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7-111

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THE KANSAS UNIVERSITY SCIENCE BULLETIN

DEVOTED TO THE PUBLICATION OF THE RESULTS OF RESEARCH BY MEMBERS OF THE UNIVERSITY OF KANSAS.

VOL. X.

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7-111

CONTENTS OF VOLUME X.

THE

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CONTENTS:

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Note on a Problem in the Theory of Algebraic Manifolds.

BY S. LEFSCHETZ.

1. In a recent paper[1] I have solved the following problem: Let $D_1, D_2, \ldots. D_s$, be algebraic manifolds belonging to an irreducible algebraic r-dimensional variety, of which the hypersurfaces $C_1, C_2, \ldots. C_\rho$, form a base. If

$$\lambda_j D_j = \Sigma \lambda_i^j C_i,$$

to obtain the genus of $D_1, D_2, \ldots. D_s$, complete intersection of the D's, in terms of the genera of the C's and of their mutual intersections. It was shown there that a formula answering the purpose exists, independent from the signs of the integers λ, and this formula was explicitly given (formula 15). This was finally applied to loci of spaces, or generalized scrolls, and to complete intersections in ordinary r-space.

The solution obtained was based upon Severi's formula for the genus of a manifold sum of two others[2]. However, the fundamental formula was derived only by an indirect method. It is the main object of the present note to show how the problem in question can be solved by a *complete inversion* of Severi's formula, inversion which in itself is not without interest. We will make use throughout of the notion of *virtual manifolds* considered at length in the note already referred to. With this notion the problem is purely one of algebra, and consists in the extension of a certain algebraic functional operation. The abstract problem underlying the symbolism used is considered in §§ 7, 8. The interesting result is obtained that the most general addition for-

1. The arithmetic genus of an algebraic manifold immersed in another. Annals of Mathematics, 1916. Vol. 17, p. 197.

2. Fundamenti per la geometria sulle varieta algebriche. Rendiconti del Circolo Mathematico di Palermo, 1909, p. 42.

mula analogous to Severi's is given by $C=A+B$; $\{(\alpha A+\beta)(\alpha B+\beta)\} = \{\alpha C+\beta\}$, which for $\alpha=\beta=1$ yields Severi's.

2. The symbols used will be practically those of my previous paper. It will be convenient to recall them briefly.

The genus of a manifold M will be designated by $[M]$. Let $A, B, \ldots . C$, be hypersurfaces of the fundamental irreducible algebraic variety V_r, $f(A, B, \ldots . C)$ a power series proceeding according to positive powers of the symbols $A, B, C \ldots \ldots$ Then

(a) We will denote by $[f(A, B, \ldots . C)]$ the result obtained when the constant term is left unchanged; the term in $A^a B^b \ldots . C^c$ is replaced by $[A^a B^b \ldots . C^c]$ if its degree is $\leqq r$, and by zero if it exceeds r.

(b) Let $F(x) = f(x, x, \ldots . x) = \sum_i a^i x^i$. We will write

$$\{f(A, B, \ldots . C)\} = [f(A, B, \ldots . C)] + (-1)^{r-1} \sum_{i=0}^{r-1} (-1)^i a^i.$$

This last definition is not identical with that of my paper, but is equivalent to it, as shown at the end of the introduction to it.

3. Let $D = C_1 + C_2$. Then[3]

$$\{1+D\} = \{(1+C_1)(1+C_2)\}. \tag{1}$$

The following generalizations of (1) have been obtained:

(a) If $D = \sum_{i=1}^{n} C_i$, $M = D_1 D_2 \ldots . D_h$, then

$$\{M(1+D)\} = \{M \prod_i (1+C_i)\}. \tag{2}$$

(b) If $D = C_1 - C_2$, $\{M(1+D)\} =$

$$\left\{M \frac{1+C_1}{1+C_2}\right\} \equiv \{M(1+C_1)(1+C_2)^{-1}\}, \tag{3}$$

where at the right the quotient is to be replaced by its expansion in power series.

From these formulas follows that if $D = \sum \lambda_i C_i$, where the λ's are any integers, then

$$\{M(1+D)\} = \{M \prod_i (1+C_i)^{\lambda_i}\}. \tag{4}$$

4. The formula to be proved will follow readily from the extension of (4) to the case where the λ's are any rational numbers. Suppose first that $\lambda D = C$, where λ is a positive integer. Then I propose to show that

$$\{M(1+D)\} = \{M(1+C)^{\frac{1}{\lambda}}\}, \tag{5}$$

3. The arithmetic genus. . . .formula 1. This is slightly more general than the formula originally given by Severi.

whatever the manifold M. Proceed by induction. The formula is easily verified when

$$M = M_s = A_1 A_2 \ldots . A_s, \; s > r.$$

Grant that it holds for $s > s_0$, I say that it is also true for $s = s_0$. For $\lambda M_{s_0} D = M_{s_0} C$;

$$\therefore \; \{ M_{s_0} (1+D)^{\lambda} \} = \{ M_{s_0} (1+C) \}. \qquad (6)$$

But $M_{s_0} D^k = M_{s_0} D^{k-1}. D$.
Hence from the assumptions made follows:

$$\{ M_{s_0} D^{k-1} (1+D) \} = \{ M_{s_0} D^{k-1} (1+C)^{\frac{1}{\lambda}} \}; k > 1$$

$$\therefore \; \{ M_{s_0} D^k \} = \{ M_{s_0} D^{k-1} (1+C)^{\frac{1}{\lambda}} - 1 \}.$$

This remains true when M_{s_0} is replaced by $M_{s_0} C^h$.

$$\therefore \; \{ M_{s_0} D^k \} = \{ M_{s_0} ((1+C)^{\frac{1}{\lambda}} - 1)^k \}, k > 1. \qquad (7)$$

From (6) follows

$$\{ M_{s_0} \sum_{k=0}^{\lambda} \binom{\lambda}{k} D^k \} = \{ M_{s_0} (1+C) \}.$$

This together with (7) gives finally

$$\{ M_{s_0} (1+C) \} =$$

$$\{ M_{s_0} \sum_{k=0}^{\lambda} \binom{\lambda}{k} D^k ((1+C)^{\frac{1}{\lambda}} - 1)^k + \lambda (1+D) - \lambda (1+C)^{\frac{1}{\lambda}} \} =$$

$$\{ M_{s_0} (((1+C)^{\frac{1}{\lambda}} - 1 + 1)^{\lambda} + \lambda (1+D) - \lambda (1+C)^{\frac{1}{\lambda}}) \}.$$

$$\therefore \; \{ M_{s_0} (1+D) - M_{s_0} (1+C)^{\frac{1}{\lambda}} \} = 0,$$

as was to be proved.

5. It remains to be shown that if $\lambda D = C_1 - C_2$, then

$$\{ M (1+D) \} = \{ M (1+C_1)^{\frac{1}{\lambda}} (1+C_2)^{-\frac{1}{\lambda}} \}. \qquad (8)$$

If we set $\lambda D = D' = C_1 - C_2$, we have by (5)

$$\{ M (1+D) \} = \{ M (1+D')^{\frac{1}{\lambda}} \}. \qquad (9)$$

Also,

$$\{M(1+D')\} = \{M(1+C_1)(1+C_2)^{-1}\};$$

$$\therefore \{MD'\} = \{M((1+C_1)(1+C_2)^{-1}-1)\}.$$

Hence finally by (9)

$$\{M(1+D)\} = \{M(1+D')^{\frac{1}{\lambda}}\} = \{M \sum_{k=0} \binom{\frac{1}{\lambda}}{k}. D'^k\} =$$

$$\{M \sum_{k=0} \binom{\frac{1}{\lambda}}{k} D^k((1+C_1)(1+C_2)^{-1}-1)^k\} =$$

$$\{M((1+C_1)(1+C_2)^{-1})^{\frac{1}{\lambda}}\} =$$

$$\{M(1+C_1)^{\frac{1}{\lambda}}(1+C_2)^{-\frac{1}{\lambda}}\}$$

as was to be proved.

6. From (5) and (8) follows that if $\lambda D = C_1 \pm C_2$, then

$$\{f(D, A, B, \ldots C)\} = \{f((1+C_1)^{\frac{1}{\lambda}}(1+C_2)^{\frac{\pm 1}{\lambda}} - 1, A, B, \ldots C)\}$$

f being as usual a power series.

Let $\lambda D = \sum_{i=1}^{\rho} \lambda_i C_i$. We may set $\lambda_1 C = \pm C_1'$, $\sum_{i=2}^{\rho} \lambda_i C_i = D_1$, according as λ_1 is positive or negative. Then $\lambda D = D_1 \pm C_1' = D_1 + \lambda_1 C_1$.

$$\therefore \{f(D, A, \ldots B)\} = \{f((1+D_1)^{\frac{1}{\lambda}}(1+C_1')^{\frac{\pm 1}{\lambda}} - 1, A, \ldots B)\},$$

and as $\{\Phi(C_1', A, \ldots B)\} = \{\Phi((1+C_1)^{\frac{\pm\lambda_1}{\lambda}} - 1, A, \ldots B)\}$ it follows

$$\{f(D, A, \ldots B)\} = \{f((1+C_1)^{\frac{\lambda_1}{\lambda}}(1+D_1)^{\frac{1}{\lambda}} - 1, A, \ldots B)\}.$$

and this by a repeated application leads to the following very general formula

$$\{f(D, A, \ldots B)\} = \{f((\prod_i (1+C_i)^{\frac{\lambda_i}{\lambda}} - 1, A, \ldots B)\}. \tag{10}$$

From this follows immediately the fundamental formula already referred to; for if

$$\lambda_j D_j = \sum_{i=1}^{\prime\prime} \lambda^j_i C_i\,, \ (j = 1, 2, \ldots . s)$$

we have

$$\{ D_1 D_2 \ldots D_s \} = \{ \prod_{i=1}^{s} (\prod_{i=1}^{\prime\prime} (1 + C_i)^{\frac{\lambda^j_i}{\lambda_j}} - 1) \}$$

which is (15) of the paper already quoted, but in a different form. If at the right we wished, as there done, to have the sign [ ] in place of { }, we would have to add an integer N. To obtain its value in terms of the λ's we remark that according to §2, N can be expressed as a polynomial in the ratios $\frac{\lambda^j_i}{\lambda_j}$.

We may therefore make $\lambda_j = 1$, for all values of j, and find N somewhat as done *loc. cit.* §4. This calculation will be omitted here.

7. The theory underlying the preceding discussion may be abstractly stated thus: Let $A_1, A_2, \ldots .$ be a finite or infinite set of magnitudes such that the sum $\Sigma \lambda_i A_i$, where the λ's are arbitrary integers, defines a quantity of the set. This quantity is supposed to remain unchanged when the A's are arbitrarily permuted together with their coefficients; that is, the commutative law of addition holds. Furthermore, the associative law is also assumed. Besides the above quantities, we consider their products in finite number $M = A_1 A_2 \ldots . A_s$. If r is an arbitrary but fixed positive integer, the number $r - s = d$ is called the dimensionality of M. We then define a function of M called its genus $[M]$ by the following properties:

(a) $[M]$ is uniquely determined when M is known.

(b) With the notations defined previously,

$$B = A_1 + A_2; \ \{ M \ (1 + B) \} = \{ M \ (1 + A_1) \ (1 + A_2) \}.$$

These two conditions suffice to make certain that if the numbers $[A_1^i \, A_2^j \ldots . A_s^k]$ are known we can obtain $[D_1 \, D_2 \ldots . D_h]$, where $\lambda_j D_j = \sum_{i=1}^{s} \lambda^j_i A_i$. In particular if there is a base in the

usual sense for the set of the A's, we can obtain all the genera $[M]$ as linear functions of the base genera.

Starting from the above properties, all the formulas obtained could be derived without having recourse to virtual manifolds, as becomes necessary with the more specialized geometric theory already discussed.

In this connection three questions present themselves:

(a) Is it possible to obtain other systems than that of algebraic manifolds contained in a given variety, having the properties outlined above?

(b) Given a base set $C_1, C_2, \ldots C_\rho$, the system defined by all the C's such that $\lambda C = \Sigma \lambda_i C_i$, and a system of integral values for the genera $[C_1^i C_2^j \ldots C_\rho^k]$, is there an irreducible algebraic variety such that its hypersurfaces are in one-one correspondence with the system so defined?

(c) Are there laws other than the one corresponding to Severi's addition formula, and yielding results of interest?

Very little may be said at present in regard to (a) and (b), but more concerning (c), which is what we proceed to do.

8. The question must first be stated more definitely. It is proposed to consider addition formulas of the type

$$\{ Mf(\overline{C_1 + C_2}) \} = \{ M \phi (C_1, C_2) \},$$

where f, ϕ, are polynomials. The simplest of this type is perhaps the following:

$$\{ Mf(\overline{C_1 + C_2}) \} = \{ Mf(C_1) f(C_2) \} \tag{11}$$

which can be easily shown to lead to the result

$$\lambda D = \Sigma \lambda_i C_i ; \ \{ f(D) \} = \Big\{ \prod_i f(C_i)^{\frac{\lambda_i}{\lambda}} \Big\} .$$

The difficulty with laws of this general type lies in the fact that unless f is linear, $[\overline{C_1 + C_2}]$ can not be obtained readily in terms of the genera $[C_1^i C_2^k]$. Restricting ourselves, therefore, to the case where $[C_1 + C_2]$ can be obtained directly in terms of these genera, we propose to show that: *Addition formulas yield-*

ing directly $[\overline{M(C_1+C_2)}]$ *in terms of the genera* $[MC_1^i\, C_2^k]$, *are all of the type* (11), *f being of the first degree.*

Suppose that $\{ M\,\overline{(A+B)} \} = \{ Mf(A,B) \}$. Clearly $f(A,B)$ must be symmetric in A, B, this being a direct consequence of the commutative law. Furthermore,

$$\{ M(A+B+C) \} = \{ M\phi(A, B, C) \},$$

where ϕ is a polynominal which, for the same reason, must be symmetric in A, B, C. Let

$$f(A, B) = \Sigma\, \alpha_{ik} A^i B^k,$$

and denote by μ the highest power at which either A or B occurs in f. Then, since

$$\phi(A, B, C) = \Sigma\, \alpha_{ik} A^i (\Sigma\, \alpha_{mn} B^m C^n)^k,$$

it is easily seen that in ϕ, A will be found at most to the power μ, while if r is sufficiently high, there will be a term containing C with the exponent μ^2.

$$\therefore\ \mu^2 = \mu,\ \mu = 1.$$

Thus the polynomial f must be of the first degree. As it is also symmetric, we have

$$f(A, B) = a(A+b)(B+b)+c,$$

where a, b, c are certain constants still in part to be determined. From this follows

$$\phi(A, B, C) = a(A+b)(a(B+b)(C+b)+c)+c,$$

and the condition of symmetry will be fulfilled only if $b = -c$, when $f(A, B) = a(A+b)(B+b) - b$.

$$\therefore\ \{ a(\overline{A+B}+b) \} = \{ a(A+b) . a(B+b) \}.$$

If we set $a = \alpha$, $ab = \beta$, we have

$$C = A+B;\ \{ M(\alpha C+\beta) \} = \{ M(\alpha A+\beta)(\alpha B+\beta) \}$$

as was to be proved.

LAWRENCE, KAN., May 30, 1916

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An Investigation of the Condition of the Drinking Water on Trains Operating In or Through Kansas.*

BY N. P. SHERWOOD.

(From the Department of Bacteriology of the University of Kansas, Lawrence.)

AT the request of Dr. S. J. Crumbine, secretary of the Kansas State Board of Health, an examination of the drinking water on trains that operate in or through Kansas was begun on May 23, 1912, at the Kansas City union station. A similar examination was made at Wichita on May 29 and 30. Fifty-four samples were taken at Kansas City from trains on the Frisco, Santa Fe, M. K. & T., Missouri Pacific, Burlington and Union Pacific railroads. The samples were plated on plain agar immediately after collection, and a set of six fermentation tubes containing Jackson's lactose-bile[1] were also inoculated. Five of these tubes were each inoculated with 1 cc. of the sample of water, and 10 cc. of the sample was planted into one large fermentation tube. This was done in order to determine approximately how many, if any, *B. coli* were present. These plates and tubes were then incubated for twenty-four hours at 37° C., and counts made.

There are present, even in good drinking-water, a few harmless bacteria, the number varying largely with the source of supply. These harmless water bacteria, however, thrive best at room temperature, and are, as a rule, inhibited when incubated at 37° C., or body temperature.

Mathews,[2] in 1893, showed that in streams presumably exposed to pollution the count at 37° C. was in the neighborhood of 100 per cc., while for unpolluted water from wells, springs and taps the count was under 30 per cc. Gage[3] has shown that for clean,

*Read before the Kansas State Board of Health, June 6, 1912.

1. Jour. Infec. Dis., March, 1906.

2. Technology Quarterly VI, 241.

3. A Study of the Number of Bacteria Developing at Different Temperatures, and of the Relation between such Numbers with Reference to their Significance in the Interpretation of Water Analysis.—Biological Studies by the Pupils of William Thompson Sedgwick, Boston, 1906.

unpolluted water the number of organisms developing at 37° C. is quite small, being, as a rule, under 50 per cc., while for polluted water the count is high. Too much stress must not be laid upon the count alone, yet one can get some idea as to whether the water is at least clean or dirty by the number of bacteria developing at the body temperature.

For a long time bacteriologists considered that the character of a water could be determined by the number of bacteria developing on agar and gelatine. Eventually bacteriologists realized that the quality or kind of bacteria present, as well as the quantity, is of prime importance. The customary qualitative test made on any sample of water is one to determine whether *Bacillus coli* is present, and if so, in what quantity. A test is made for this particular intestinal organism, because if it is present it is easily found and identified, and since it is a normal inhabitant of the colon or large intestines of warm-blooded animals, it indicates, when present in sufficient quantity, *i. e.*, 1 per cc. or more, pollution with animal waste.

In England, where the sewage is much more concentrated than in America, sewage streptococci are looked for in water examination instead of *B. coli*. The English argue, with reason, that the sewage streptococci are more delicate than *Bacillus coli*, and hence their presence in a water is a certain indication of *recent* sewage pollution. In these examinations streptococci were looked for as well as *Bacillus coli*. Daniel D. Jackson, in the *Journal of Infectious Diseases*, March, 1907, defines *Bacillus coli* as a Gram negative organism capable of fermenting both dextrose and lactose, with the production of carbon dioxide and hydrogen, which does not liquefy gelatin in fourteen days and which is morphologically a rod.

It is a well-known fact that ordinary ox bile has an inhibitive action on the majority of bacteria outside of those belonging to the typhoid and colon groups. Also that comparatively few organisms outside the colon group ferment lactose. Hence lactose bile—ordinary ox bile to which has been added one per cent peptone and one per cent lactose—is a medium made use of in examining a water for *Bacillus coli*. Measured quantities of water are added to fermentation tubes containing lactose bile; and if *Bacillus coli* is present the lactose will be fermented and carbon dioxide and hydrogen will be given off. When gas showed up in any of the fermentation tubes, confirmatory tests were made to see whether it was *B. coli* or some other organism that was causing

the fermentation. As a rule, in about 90 per cent of the cases *B. coli* will be found to be the active agent. *Streptococcus pyogenes* was finally identified by its characteristic growth on blood agar. As a general thing, only one sample was taken from each train, and that was collected from the chair car next to the smoker.

The results of the work done at Kansas City, Mo., and at Wichita, Kan., are shown by the tables on pages 16, 17, and 18.

Report on examination of water taken from coolers of trains arriving and departing from Kansas City, Mo., and Wichita, Kan.

FROM KANSAS CITY, MO., MAY 23 AND 24, 1912.

Sample No.....	Train No.	NAME OF RAILROAD.	Time.	Train arriving or departing...	Date, 1912.	Bacteria per cc. on agar at 37° C, 24 hours.	Gas in lactose bile.							Approximate number of *B. coli* per 10 cc.	Remarks.
							1 cc.					10 cc.	Confirmatory test.		
							1	2	3	4	5				
1	102	Frisco	5:00 p. m.	A	5-23	100	—	—	—	—	—	—	None.	None.	—
2	125	Frisco	5:05 p. m.	D	5-23	150	—	—	—	—	—	—	....	None.	—
3	10	A. T. & S. F	5:05 p. m.	D	5-23	650	—	—	—	—	—	—	....	None.	—
4	24	M. K. & T	5:05 p. m.	A	5-23	300	—	—	—	—	—	—	....	None.	—
5	12	Rock Island	5:10 p. m.	A	5-23	1,400	—	—	—	—	—	—	....	....	—
6	29	M. K. & T	5:30 p. m.	D	5-23	250	—	—	—	—	—	—	....	....	—
7	137	Frisco	5:35 p. m.	D	5-23	850	—	—	—	—	—	—	....	....	—
8	1	Mo. Pacific	6:00 p. m.	D	5-23	1,200	+	—	—	—	—	+	+	2	—
9	39	Rock Island	6:10 p. m.	D	5-23	200	—	—	—	—	—	—	....	....	—
10	106	Mo. Pacific	6:15 p. m.	A	5-23	400	—	—	—	—	—	+	+	1	—
11	105	Frisco	6:15 p. m.	D	5-23	750	+	—	+	—	—	+	+	4	—
12	119	Mo. Pacific	6:20 p. m.	D	5-25	800	+	+	—	—	—	+	+	4	—
13	43	Burlington	6:35 p. m.	D	5-23	500	—	—	—	—	—	—	—	None.	—
14	111	Frisco	9:10 p. m.	D	5-23	500	—	—	—	—	—	+	+	1	—
15	11	A. T. & S. F	9:25 p. m.	D	5-23	650	—	+	—	—	—	+	+	2	—
16	36	Rock Island	9:45 p. m.	A	5-23	250	—	—	—	—	—	—	....	None.	—
17	103	Mo. Pacific	9:50 p. m.	D	5-23	300	—	—	—	—	—	—	....	None.	—
18	17	A. T. & S. F	10:00 p. m.	D	5-23	800	—	—	—	—	—	—	....	None.	—
19	21	M. K. & T	10:00 p. m.	D	5-23	950	—	+	+	—	—	+	+	4	—
20	112	Mo. Pacific	10:20 p. m.	A	5-23	150	—	—	—	—	—	—	....	None.	—
21	203	A. T. & S. F	10:45 p. m.	D	5-23	1,100	—	—	—	—	—	—	....	None.	—
22	1	Rock Island	11:15 p. m.	D	5-23	800	+	+	—	+	—	+	+	6	—
23	23	Rock Island	11:30 p. m.	D	5-23	250	—	—	—	—	—	—	....	None.	—
24	25	M. K. & T	2:20 a. m.	D	5-24	1,500	—	—	—	—	—	+	+	1	—
25	210	Mo. Pacific	2:00 a. m.	D	5-24	40	—	—	—	—	—	—	—	None.	—
26	23	Rock Island	6:15 a. m.	A	5-24	250	—	—	—	—	—	+	+	1	—
27	8	A. T. & S. F	6:30 a. m.	A	5-24	700	—	—	—	—	—	—	—	None.	*Streptococcus pyogenes* present.
28	18	A. T. & S. F	7:00 a. m.	A	5-24	550	—	—	—	—	—	—	....	None.	—
29	12	A. T. & S. F	7:10 a. m.	A	5-24	620	—	—	—	—	—	—	....	None.	—
30	104	Frisco	7:00 a. m.	A	5-24	200	—	—	—	—	—	—	....	None.	—
31	22	M. K. & T	7:20 a. m.	A	5-24	300	—	—	—	—	—	—	....	None.	—
32	35	Rock Island	7:55 a. m.	D	5-24	1,000	—	—	—	—	—	+	—	None.	*B. mycoides.*
33	113	A. T. & S. F	8:01 a. m.	D	5-24	600	—	—	—	—	—	—	....	None.	—
34	107	Union Pacific	8:05 a. m.	D	5-24	1,100	—	—	—	—	—	—	—	1	*Streptococcus pyogenes* present.
35	111	Mo. Pacific	8:15 a. m.	D	5-24	1,000	+	—	+	+	+	+	+	8	—
36	127	Frisco	8:30 a. m.	D	5-24	30	—	—	—	—	—	+	Bubble.	None.	*B. mycoides.*

FROM KANSAS CITY, MO., MAY 23 AND 24, 1912—CONCLUDED.

Sample No.	Train No.	NAME OF RAILROAD.	Time.	Train arriving or departing.	Date, 1912.	Bacteria per cc. on agar at 37° C, 24 hours.	Gas in lactose bile. 1 cc. 1	2	3	4	5	10 cc.	Confirmatory test.	Approximate number of *B. coli* per 10 cc.	Remarks.
37	201	A. T. & S. F.	9:00 a. m.	D	5-24	150	—	—	—	—	—	—	.....	None.	—
38	3	A. T. & S. F.	9:10 a. m.	D	5-24	1,200	—	+	+	+	—	+	+	6	—
39	110	Union Pacific	9:15 a. m.	A	5-24	1,800	+	+	+	+	+	+	+	10	—
40	102	Mo. Pacific	9:20 a. m.	A	5-24	700	+	+	+	—	—	+	+	6	—
41	518	A. T. & S. F.	9:40 a. m.	D	5-24	100	—	—	—	—	—	—	.....	None.	—
42	112	Frisco	9:59 a. m.	A	5-24	1,250	—	—	—	—	—	+	+	1	—
43	9	A. T. & S. F.	9:[illegible]0 a. m.	A	5-24	950	+	+	—	—	+	+	+	6	—
44	11	Rock Island	10:[illegible]0 a. m.	D	5-24	500	—	—	—	—	—	—	.....	None.	—
45	110	A. T. & S. F.	—— a. m.	A	5-24	400	—	—	—	—	—	—	.....	None.	—
46	.....	.....	—— a. m.	.....	5-24	500	—	—	—	—	—	+	+	1	—
47	.....	.....	—— a. m.	.....	5-24	900	—	—	—	—	—	+	+	1	—
48	531	Mo. Pacific	4:05 p. m.	D	5-24	75	—	—	—	—	—	—	—	None.	—
49	105	Union Pacific	4:10 p. m.	D	5-24	1,200	—	—	—	—	—	—	—	None.	—
50	1316	Frisco	4:15 p. m.	A	5-24	90	—	—	—	—	—	—	.....	None.	—
51	111	A. T. & S. F.	4:15 p. m.	A	5-24	1,200	—	—	—	—	—	—	.....	None.	—
52	109	A. T. & S. F.	4:30 p. m.	A	5-24	800	—	—	—	—	—	—	.....	None.	—
53	131	Mo. Pacific	4:30 p.	D	5-24	850	—	—	—	—	—	—	—	None.	—
54	5	A. T. & S. F.	9:40 p. m.	D	5-24	30	—	—	—	—	—	—	.....	None.	Chair car.
55	5	A. T. & S. F.	9:40 p. m.	D	5-24	25	—	—	—	—	—	—	.....	None.	Smoking car.
.....	.....	Tap	.....	.....	5-24	20	—	—	—	—	—	—	.....	None.	Station.
.....	.....	Union Pacific*	.....	.....	5-24	30	—	—	—	—	—	—	.....	None.	—

*Sand springs water.

FROM WICHITA, KAN., MAY 29 AND 30, 1912.

Sample No.	Train No.	Name of Railroad.	Time.	Train arriving or departing.	Date, 1912.	Bacteria per cc. on agar at 37° C, 24 hours.	Gas in lactose bile. 1 cc. 1	2	3	4	5	10 cc.	Confirmatory test.	Approximate number of *B. coli* per 10 cc.	Remarks.
1	12	A. T. & S. F.	12:26 a. m.		5-30	130	−	−	−	−	−	−		None.	——
2	32	Rock Island	12:55 a. m.		5-30	150	−	−	−	−	−	−		None.	——
3	403	Mo. Pacific	7:30 a. m.		5-30	400	−	−	−	−	−	−		None.	*B. pyocyaneus* present; iced at Yates Center.
4	433	Mo. Pacific	7:50 a. m.		5-30	300	−	−	−	−	−	−		None.	*B. pyocyaneus* present; iced and H_2O at Wichita.
5	703	Mo. Pacific	7:45 a. m.		5-30	450	−	−	−	−	−	−		None.	H_2O at Wichita.
6	117	A. T. & S. F.	8:20 a. m.		5-30	1,200	+	+	+	+	+	+	+	10	——
7	309	Frisco	8:25 a. m.		5-30	300	−	−	−	−	−	−		None.	Car 309. Iced at Minette and Walire.
8	309	Frisco	8:25 a. m.		5-30	150	−	−	−	−	−	−		None.	Car 1016.
9	517	A. T. & S. F., Englewood branch	8:30 a. m.	D	5-29	550	+	+	+	+	+	+	+	10	Car 137; iced and H_2O at Wichita.
10	1	Orient	8:35 a. m.	D	5-29	500	+	+	+	−	−	+	+	6	Iced and H_2O at Wichita.
11	12	Rock Island	9:50 a. m.		5-29	650	−	+	+	+	+	+	+	8	Iced at Caldwell; H_2O at Chickasha, Okla.
12	406	A. T. & S. F.	10:45 a. m.		5-29	500	−	−	−	−	−	−	−	10	Iced at Pratt, also water.
13	406	A. T. & S. F.	11:10 a. m.		5-29	600	+	+	−	−	−	+	+	4	Iced at Arkansas City; H_2O at Purcell.
14	8	Frisco	11:15 p. m.		5-29	600	−	−	−	−	−	−		None.	Car 62.
15	8	Frisco	11:15 p. m.		5-29	550	−	−	−	−	−	−		None.	Car 1030.
16	16	A. T. & S. F.	1:50 p. m.		5-29	100	−	−	−	−	−	−		None.	——
17	518	A. T. & S. F., Englewood branch	1:30 p. m.	A	5-29	1,200	+	+	+	+	−	+	+	8	——
18	505	A. T. & S. F.	5:25 p. m.		5-30	350	−	−	−	−	−	−		None.	*B. pyocyaneus* present.
19	710	Mo. Pacific	6:20 p. m.		5-30	300	−	−	−	−	−	−		None.	H_2O at Nevada; Ice Coffeyville.
20	405	Mo. Pacific	6:25 p. m.	A	5-30	350	−	−	−	−	−	−		None.	——
21	2	Orient	7:00 p. m.	A	5-30	450	−	−	−	−	−	−		None.	——
22	24	Rock Island	9:20 p. m.		5-30	500	+	+	+	+	+	+	+	10	*B. pyocyaneus* present.
23		Tap (city)	8:00 a. m.			60	−	−	−	−	−	−		None.	Tap at depot A. T. & S. F.
24	2	Midland Valley	8:00 a. m.	D		400	+	−	+	+	−	+	+	6	Iced and H_2O at Wichita.
25		Tap				90	−	−	−	−	−	−		None.	Tap at Mo. Pacific.
26		Tap				80	−	−	−	−	−	−		None.	Tap at Rock Island.
27		Tap				60	−	−	−	−	−	−		None.	Tap at Frisco.

Altogether there were seventy-eight samples taken, and in order to simplify matters these have been rearranged into four groups according to the degree of pollution, beginning with the worst samples in group I and ending with the purest water in group IV.

Group I includes all those samples having at least 10 colon organisms in 10 cc. of water, or 1 per cc. of the water examined, and is as follows:

GROUP I.

City.	Sample No.	Train No.	Name of Railroad.	Time.	Arriving or departing.	Date.	Count per cc. on agar at 37° C., 24 hours.	Approximate number of *B. coli* in 10 cc.
Kansas City, Mo..	39	110	Union Pacific....	9:15 p. m.	A	5-24	1,800	10
Wichita..........	6	117	A. T. & S. F......	8:20 p. m.	D	5-29	1,200	10
Wichita..........	9	517	A. T. & S. F., Englew'd branch,	8:30 a. m.	D	5-29	550	10
Wichita..........	12	506	A. T. & S. F......	10:45 a. m.	....	5-29	500	10
Wichita..........	22	24	Rock Island......	9:20 p. m.	....	5-30	500	10

Group II includes those having from 6 to 8 *B. coli* in 10 cc. of water:

GROUP II.

City.	Sample No.	Train No.	Name of Railroad	Time.	Arriving or departing.	Date.	Count per cc. on agar at 37° C., 24 hours.	Approximate number of *B. coli* in 10 cc.
Kansas City, Mo..	1	1	Rock Island	11:15 p. m.	D	5-23	800	6
Kansas City, Mo..	35	111	Missouri Pacific...	8:15 a. m.	D	5-24	1,000	8
Kansas City, Mo..	38	3	A. T. & S. F......	9:10 a. m.	D	5-24	1,200	6
Kansas City, Mo:.	40	102	Missouri Pacific...	9:20 a. m.	A	5-24	700	6
Wichita..........	1	1	Orient...........	8:35 a. m.	D	5-29	500	6
Wichita..........	11	12	Rock Island......	9:50 a. m.	....	5-29	650	8
Wichita..........	17	518	A. T. & S. F., Englew'd branch,	1:30 p. m.	A	5-29	1,200	8
Wichita..........	24	2	Midland Valley...	8:00 a. m.	D	5-30	400	6

Group III: There are fourteen samples having from 1 to 4 *B. coli* per 10 cc. of the water. In two of them both *Streptococcus pyogenes* as well as *B. coli* was present.

Group IV: There are forty-nine samples in which no *B. coli* were present in 10 cc. of the water.

In group I there are five samples, or 6.4 per cent, containing 10 colon bacteria in 10 cc. of the water, or 1 per cc., with bacterial counts ranging from 500 to 1800 per cc. In one sample *Bacillus pyocyaneus*, the green-pus organism, was found to be present. Waters in this group are decidedly unfit for drinking purposes.

In group II there are nine samples, or 11.4 per cent, in which there are 6 to 8 colon organisms in each ten cc. of the water, with

the bacterial count ranging between 400 and 1200 per cc. These waters are open to strong suspicion and should not be drunk.

In group III there are fourteen samples, or 17.8 per cent, having from 1 to 4 *B. coli* in each 10 cc. of the water, with comparatively high counts.

Of the forty-nine samples in which no *B. coli* was found, twenty-two of them, or 44.9 per cent, show counts developing at body temperature of over 350 bacteria per cc. and eighteen of these have 500 or more bacteria per cc. Thirty-one samples show counts under 500 per cc., and of these twenty-seven, or about one-third of the total number of samples examined, are under 350 per cc. That is, if we attribute any significance—and we must—to the number of bacteria developing at body temperature, and adopt even 350 per cc. as a dividing line between clean and dirty water, we find that of the seventy-eight samples examined, only twenty-seven, or about one-third, showed themselves to be sufficiently clean for drinking purposes.

The possible sources of pollution in these samples of water may be grouped as follows:

1. From the original water supply.
2. From the water used in the ice.
3. From the dirt adhering to the ice.
4. From the hands or person of the individual handling the ice.
5. From the buckets, wheelbarrows, etc., used in carrying and handling the ice.
6. From carelessness in washing the tanks as to thoroughness and as to kind of water used in washing.

The following data as to the water and ice furnished passenger trains in Kansas was supplied by the railroads to Doctor Crumbine:

RAILROAD AND STATION.	Water or ice.	Source.	Method of handling.
Rock Island:			
Armourdale	Water	Railroad plant	Buckets and tongs.
Armourdale	Ice	Manufacturing plant	Buckets and tongs.
Horton	Water	Well	———
Horton	Ice		Tongs.
Topeka	Water	City	———
Topeka	Ice	Manufacturing plant	Buckets.
McFarland	Water	Well	———
McFarland	Ice	Manufacturing plant	Buckets.
Herington	Water	Railroad plant	———
Herington	Ice	Manufacturing plant	Tongs.
Caldwell	Water	City	———
Caldwell	Ice	Manufacturing plant	Buckets.
Liberal	Water	Railroad plant	———
Liberal	Ice	Manufacturing plant	Buckets.
Pratt	Water	Railroad plant	———
Pratt	Ice	Manufacturing plant	Buckets.
Belleville	Water	City	———
Belleville	Ice	Natural	Buckets.
Goodland	Water	Railroad plant	———
Goodland	Ice	Manufacturing plant	Buckets.
Phillipsburg	Water	Piped from Glade	———
M. K. & T.:			
Parsons	Water	City	———
Parsons	Ice	Manufacturing plant	———
Kansas City	Water	City	———
Junction City	Water	City	———
Junction City	Ice	Manufacturing plant	———
Iola	Water	City	———
Iola	Ice	Manufacturing plant	———
Union Pacific:			
Armstrong	Water	City	———
Armstrong	Ice	Natural and manufactured	———
Manhattan	Water	Railroad plant	———
Manhattan	Ice	Natural and manufactured	———
Junction City	Water	City	———
Junction City	Ice	Natural and artificial	———
Solomon	Water	Railroad plant	———
Solomon	Ice	Natural and manufactured	———
Salina	Water	Railroad plant	———
Salina	Ice	Natural and manufactured	———
Ellis	Water	Railroad plant	———
Ellis	Ice	Natural and manufactured	———
Leavenworth	Water	City	———
Leavenworth	Ice	Natural and manufactured	———
Onaga	Water	Railroad plant	———
Onaga	Ice	Natural and manufactured	———
Miltonvale	Water	Railroad plant	———
Miltonvale	Ice	Natural and manufactured	———
Belleville	Water	Railroad plant	———
Belleville	Ice	Manufactured	———
Beloit	Water	Railroad plant	———
Beloit	Ice	Manufactured	———
Orient:			
Wichita	Water	Railroad plant	———
Wichita	Ice	Manufactured	———
Concordia	Water	Railroad plant	———
Concordia	Ice	Natural	Buckets.
Atchison	Water	City	———
Atchison	Ice	Natural	Buckets.
Oberlin	Water	Railroad plant	Put in tanks by roundhouse men.
Oberlin	Ice		———
St. Francis	Water	Railroad plant	Put in tanks by roundhouse men.
St. Francis	Ice		———

All of the water supplies investigated showed themselves to be good, potable water. An inspection of the ice used in the coolers quite often revealed the presence of dirt in artificial as well as natural ice.

The presence of *B. pyocyaneus* is of no great significance, as organisms closely resembling or identical with it are often found in normal waters. Its source could not be determined, but was probably from the air or dirt. No cuts or wounds were found on the hands of those handling the ice, water or coolers. As mentioned above, one must not lay too much stress on a body-temperature count alone, yet from the data obtained at Kansas City it will be noted that of those trains watered at Kansas City, nearly 20 per cent had counts under 100 per cc., and 12 per cent had counts of 40 per cc. or less, while the sources of supply showed a count of 20 per cc. with no *B. coli* present in 10 cc. From this data, and after making a sanitary survey of conditions, it seems that there is no excuse for so many samples having body temperature counts of over 350 per cc., and that these high counts show carelessness in cleaning the coolers and handling the ice.

The publication of this paper at this time has been made because of its historical interest and because of numerous requests for reprints of the report. It should be understood that these conditions probably in no way exist to-day since the federal government and the state of Kansas have carefully carried out investigations, and laws have been passed regulating the handling of drinking water on common carriers. This investigation which Doctor Crumbine had carried out was, perhaps, the first of its kind in the United States. As a result of it, the Kansas State Board of Health formulated rules and regulations governing drinking water on trains, which antedated the federal government's action over two years. He made use of this and other data at his command in his pioneer work for the betterment of conditions of drinking water on common carriers.

Since this investigation was made much research work and improvement has been done along lines of water investigation. The value of lactose bile has been questioned because of its inhibitive action on the colon group, and some interesting work along the line of differentiation between fecal and other strains of bacillus coli has been carried out.

□

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A Study of the Relative Efficiency of the Various Differential Staining Methods Used in Identifying the Tubercle Bacillus.*

BY NOBLE P. SHERWOOD.

(From the Department of Bacteriology of the University of Kansas, Lawrence, Kan.)

THERE has been much discussion as to the classification of the tubercle, leprosy, smegma, grass, and butter bacilli. Migula classifies them with the Bactereaceæ, while Abbot and others have placed them among the trichobacteria. They differ from the rest of the bacteria in that they contain fats, waxes and alcohols, which render them quite difficult to stain with the ordinary basic anilin dyes, such as methylene blue, basic fuchsin, or gentian violet. By covering a dried and fixed preparation of these bacteria on a slide with basic fuchsin or gentian violet, and steaming it from three to five minutes over a free flame, the stain is taken up and retained by these organisms with much greater tenacity than practically any other members of the bacterial kingdom. In fact, when fuchsin is steamed into them they resist decolorization by three to five per cent aqueous solution of any of the mineral acids for thirty minutes to an hour or even longer, whereas other bacteria are decolorized by this treatment. For this reason the tubercle, leprosy, smegma, grass, and butter bacilli are called the acid-fast group of bacteria. Jordan[1] says that this property is due largely to the presence of mykol, one of the higher alcohols. Spores of such organisms as *Bacillus subtilus* and *Bacillus anthracis* are also acid-fast, although the respective organisms are not.

This property of resistance to decolorization with mineral acids, when once the organisms have the stain steamed into them, has

* Read before Kansas Academy of Science January, 1916.

been taken advantage of by bacteriologists and made use of in the routine laboratory examination of sputum, urine, pus, etc., for tubercle bacilli in suspected cases of tuberculosis, and by many in examining butter, milk and other foods for the presence of tubercle bacilli. Now, as was stated above, this acid-fastness or acid-proofness is not the property of just one organism but of a small group of organisms. It has been the aim of many workers to find some method of decolorization that would enable one to differentiate between true tubercle bacilli and other members of this group. This seems to be desirable in order to eliminate possibilities of error in the laboratory examination of suspected tuberculous material, since the smegma bacillus is very commonly found in normal smegma, and has been reported as found, occasionally, in gangrenous conditions of the lungs, on the tonsils, in the tartar from the teeth, from scrapings from the tongue, and on the skin in the inguinal and axillary regions. The butter bacillus and grass bacillus may be present in butter, in other dairy products, and foods. Hence, either of these last two organisms may be found present in the mouths of normal individuals. Since tuberculosis is caused only by the tubercle bacillus and not by any other members of the acid-fast group, it is desirable when examining suspected material to rule out possibilities of error due to the presence of these other organisms. Many staining methods have been suggested, tried and recommended. They may be grouped into five groups as to theories and methods:

1. That true tubercle bacilli differ from the rest of the acid-fast group in their resistance to decolorization with 25 or 30 per cent aqueous solution of the mineral acids. All of the acid-fast organisms, excepting true tubercle bacilli, are said to be decolorized.

2. That while this group is acid-fast, only true tubercle bacilli are acid-alcohol fast. Hence, acidulated alcohol (2 to 3 per cent hydrochloric or nitric acids in from 70 per cent to absolute alcohol) has been used as a differential agent.

3. Some modification of (2), such as Pappenheim's, where rosalic acid is used in connection with glycerine and absolute alcohol.

4. That it is necessary and important to remove the fats and use strong concentrations of mineral acids and absolute alcohol to decolorize everything except the tubercle bacillus.

5. Fonte's method, which is a combination of the acid-fast and Gram's stain, as described below.

As a method typifying the first theory, Gabbet's[2] is perhaps the best. In this method the preparation is made and stained with steaming carbol-fuchsin from three to five minutes. The excess of staining fluid is drained off without washing and is replaced by Gabbet's methylene blue solution (2 gr. M. B.; sulphuric acid, 25 cc.; water, 75 cc.). This solution is allowed to act for from one to three minutes and is then washed off with water and the preparation dried and examined. The tubercle bacilli will appear as bright red rods, while all the other organisms are said to be stained blue.

The Ziehl-Neelsen[3] method comes under the second group. In this method the organisms are stained with steaming carbol-fuchsin from three to five minutes and decolorized with acidulated alcohol for several minutes, or until no more color comes from the slide. It is then washed in water and counter-stained with Loeffler's methylene blue. The tubercle bacillus will appear red, while all the other bacteria are supposed to be blue.

A modification of this method, which is reported to have given greater efficiency, is Pappenheim's[4] method. The preliminary staining is carried out as above. The specimen is then drained and covered with decolorizing solution, which is made by dissolving one gram of rosalic acid in 100 cc. of absolute alcohol, saturating the mixture with methylene blue and adding twenty parts of glycerine. The slide is then washed in water, dried between blotting paper, and examined with the immersion lens. The tubercle bacilli are stained red and all the other organisms are said to be blue.

As an example of group IV is Bunge and Trantenroth's[5] method. After fixation of the smear the fat is removed by soaking the specimens in absolute alcohol. The preparation is now covered with a 5 per cent solution of chromic acid for fifteen minutes, after which it is washed with water. The smear is stained with steaming carbol-fuchsin, decolorized with 16 per cent sulphuric acid for three minutes, and is then counter-stained for five minutes in a concentrated alcoholic solution of methylene blue. This method is said to give the tubercle bacillus a distinct red color, while the smegma bacillus is blue.

Fonte's[6] method for the differentiation of the tubercle bacillus from the rest of the acid-fast group is as follows:

1. Stain the dried and fixed preparation with steaming carbol-fuchsin for three minutes.
2. Wash with tap water.

3. Stain in the cold, with carbol-gentian violet, for two or three minutes.

4. Drain off the stain and treat with Lugol's solution until no more metallic mirrors appear. Blot dry with filter paper.

5. Decolorize with absolute alcohol and ether (equal parts) until no more color comes from the slide.

6. Counter-stain with methylene blue.

7. Wash in distilled water and dry, and examine.

The tubercle bacilli appear as bright red rods containing blue granules. The other members of the acid-fast group, as well as other Gram positive organisms, appear Gram positive.

The scope of this paper is an investigation of the value of Gabbet's, Ziehl-Neelsen's, Pappenheim's, Bunge and Trantenroth's, and Fonte's methods as a means of differentiating between *Bacillus tuberculosis, B. lepræ, B. smegma,* Moeller's grass bacillus, and the butter bacillus.

This work was undertaken because of the various conflicting statements in the literature as to the value of these solutions in differentiating between true tubercle bacilli and the rest of the acid-fast group; because Pappenheim's, Bunge and Trantenroth's, and Ziehl-Neelsen's methods are accepted and used in many laboratories as giving a reliable differentiation.

Alvarez and Travil[7] (1885), Klemperer and Bittu,[8] and Cowie[20] (1900-'01), as well as others, have described peculiar bacilli in smegma taken from the genitals of man and the lower animals, as well as from moist skin in the folds of the groin, the axilla and the arms. They also mention its presence in normal urine and sometimes in saliva and sputum. They are described as morphologically resembling the tubercle bacillus and resisting decolorization by mineral acids, but being decolorized by alcohol.

Moeller[9] (1898) found in milk, butter, timothy hay, cow dung, etc., acid-fast organisms. They were acid-alcohol-fast but nonpathogenic for laboratory animals. Moeller (1902) cultivated acid-fast organisms from the skin. He concluded that all acid-fast organisms that he had worked with were tinctorially like the true tubercle bacillus.

Marzinowski[10] (1900) found saprophytic acid-fast organisms associated with bronchitis. Frinkel[11] (1898), and Rabinovitch[13] (1900), found acid-fast organisms associated with pulmonary gangrene; they were saprophytes. Petri (1897), Rabinovitch[12] (1899) and Korn[14] (1899) have described as *Bacillus butyricus* an acid-fast organism, morphologically like the tubercle bacillus,

which may at times be found in butter. They think it would be mistaken for the tubercle bacillus from its morphology and staining reactions. It could be differentiated on cultural grounds, inasmuch as it grows readily on artificial media, whereas the tubercle bacillus does not.

Abbot and Gildersleeve[15] (1902) concluded from their study of the acid-fast group that 30 per cent nitric acid in water is a fairly satisfactory method of differentiation. They state that the majority of acid-fast bacteria are unable to resist decolorization with this nitric acid solution, whereas it does not affect the stain in the tubercle bacillus. They would also place the acid-fast organisms in the group of *Actinomycetes*. In regard to animal inoculation, they state that some of the acid-fast bacteria other than the tubercle bacillus are capable of causing in rabbits and guinea pigs nodular lesions suggestive of tubercles; that these lesions, while often very much like tubercles in their histological structure, may nevertheless be distinguished from them by the following peculiarities:

A. When occurring as the result of intravenous inoculation, they are always seen in the kidneys, only occasionally in the lungs, and practically not at all in the other organs.

B. They constitute a localized lesion, having no tendency to dissemination, metastasis, or progressive destruction of tissue, by caseation.

C. They tend to terminate in suppuration or organization rather than in progressive caseation as in the case with tubercles.

D. They are more commonly and conspicuously marked by the *Actinomycetes* type of development of the organisms than is the case with true tubercles, and these *Actinomycetes* are less resistant to decolorization by strong acid solutions than are those seen in tubercles.

For the experimental work of this paper, cultures of the various members of the acid-fast group were obtained from year to year, from the American Museum of Natural History. A culture of the tubercle bacillus was obtained from the University of Michigan and one from the University of Chicago. Two cultures (two strains) of the leprosy bacillus were obtained from Tulane University. Sputums from clinical cases of tuberculosis were also examined. In addition to the pure cultures of *B. smegmatis* obtained from the American Museum, normal smegma was secured from a number of individuals and used in these experiments.

Several samples of butter were also examined for the butter bacillus.

The pure cultures were carried along on glycerine agar, plain agar, and in glycerine broth. Cultures varying from one to three weeks in age were found satisfactory.

In studying the relative efficiency of Gabbet's, Pappenheim's, acid-alcohol, etc., as decolorizing agents the standard was the number of acid-fast organisms present when decolorized with 3 per cent nitric acid in water. Several slides were run on each of these as controls and in making estimates.

In the following table four plus (+ + + +) indicates complete acid-fastness with the reagent used, while a minus sign (—) indicates non-acid-fastness. The intermediate degrees are indicated by the number of plus signs, varying between the two limits. Where only a few organisms retain the stain, and that only to a slight degree, the double dagger is used (††).

DATA.

Source of Organism.	Staining and decolorizing methods—counter-stained with methylene blue.					
	3 per ct. nitric acid in water.	Gabbot's.	Pappenheim's.	Acid alcohol.	Bunge and Trantenroth's.	Fonte's.
B. tuberculosis.						
1. Cult., A. M., '12	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	
2. Cult., A. M., '13	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	
3. Cult., A. M., '14	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	—
4. Cult., A. M., '15	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	—
5. Cult., U. of M	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	—
6. Cult., U. of C	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	—
7. Sputums from 29 positive cases	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + ††
8. Sputum	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	††
9. Urine	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	††
10. Pus from cervical lymph glands	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +	+ + + +
B. lepræ.						
1. Cult., A. M., '13	+ + + +	+ + + +	+ + + ††	+ + + +	+ + + ††	
2. Cult., A. M., '14	+ + + +	+ + + +	+ + + ††	+ + + +	+ + + ††	—
3. Cult., A. M., '15	+ + + +	+ + + +	+ + + ††	+ + + +	+ + + ††	—
4. (2) Cult., Tulane	+ + + +	+ + + +	+ + + ††	+ + + +	+ + + ††	—
B. smegmatis.						
1. Cult., A. M., '12	— — — —	— — — —	— — —	— — — —	— —	
2. Cult., A. M., '13	— — — —	— — — —	— — —	— — — —	— —	
3. Cult., A. M., '14	— — — —	— — — —	— — ††††	— — — —	— ††	—
4. Cult., A. M., '15	+ + + +	+ + + +	+ + ††	+ + + +	+ + ††	—
5. Cult. from normal smegma (a)	+ + + +	+ + + +	††	+ +	+ †† —	—
6. Normal smegma smears	Many acid-fast.	+ + + +	††	+ +	+ ††	—
7. Cult. from normal smegma (b)	+ + + +	+ + +	— — —	††	††	—
8. Normal smegma smears (b)	Many acid-fast.	+ + +	—	††	+	—
9. Normal smegma smears (c)	A few acid-fast.	—	—	—	—	—
10. Normal smegma smears	A few acid-fast.	—	—	—	—	—
11. Normal smegma smears	Many acid-fast.	+ + + +	††	+ ††	+ ††	—
12. Normal smegma smears	A few acid-fast.	††	—	—	—	—
13. (15) Normal smegma smears	None acid-fast.	—	—	—	—	—
B. Rabinowitch. (*Butter bacillus.*)						
1. Cult., A. M., '12	Many acid-fast.	+ + + +	+ + + ††	+ + + +	+ + +	
2. Cult., A. M., '13	Many acid-fast.	+ + + +	+ + + ††	+ + + +	+ + +	—
3. Cult., A. M., '14	Many acid-fast.	+ + + +	+ + + ††	+ + + +	+ + +	—
Moeller's grass bacillus.						
1. Cult., A. M., '12	Many acid-fast.	+ + + +	+ + ††††	+ + + +	+ ††	—
2. Cult., A. M., '13	Many acid-fast.	+ + + +	+ + +	+ + + +	+ +	—
3. Cult., A. M., '14	Many acid-fast.	+ + + +	+ + ††	+ + + +	+ †† — —	—
4. Cult., A. M., '15	Many acid-fast.	+ + + +	+ + ††	+ + + +	+ ††	—

DISCUSSION.

It will be observed that by Fonte's method all of the members of the acid-fast group of organisms growing on culture media saprophytically were decolorized. This includes the pure cultures of the tubercle bacillus. None of the other methods would completely decolorize any of the members of this group of organisms, Bunge and Trantenroth's and Pappenheim's having as a rule a greater efficiency than Gabbet's or the Ziehl-Neelsen method, but even with these there were always some organisms of each member of the group retaining the fuchsin stain. On the other hand, in twenty-nine positive sputums from clinical cases of tuberculosis the tubercle bacilli remained acid-fast by Fonte's method as well as by the other methods. One sample of sputum from a doubtful case of tuberculosis (8), however, which when examined by Fonte's method showed only a few weakly acid-fast organisms containing the characteristic blue granules, appeared entirely different by the Ziehl-Neelsen and other methods, showing by these fifty and seventy-five strongly acid-fast organisms per field. This sputum was treated for a few minutes with 15 per cent antiformin, and after repeated washings the sediment was injected into guinea pigs. The injected sediment was rich in acid-fast organisms by the Ziehl-Neelsen method. After three months the pigs were normal in weight, did not respond to the tuberculin test, and at *post mortem* showed no evidence of tuberculosis except for the slight enlargement of a few mesenteric lymph glands. The tissue examination was negative. A similar report can be made in regard to urine sample (9), where many strongly acid-fast organisms were found by Gabbet's, Ziehl-Neelsen's, Pappenheim's, and Bunge and Trantenroth's methods, while only a few very weakly acid-fast organisms were in evidence by Fonte's method. Animal inoculation gave negative results. Clinically this case is not tuberculosis at present. In regard to the action of these two strains of acid-fast organisms one of the following must be true: (1) That the organisms are not tubercle bacilli; (2) that if they are they are so avirulent as not to cause tuberculosis in guinea pigs; (3) that the guinea pigs were unusually resistant to tubercle bacilli; (4) that the bacteria were attenuated or killed by the antiformin. In view of the fact that saprophytic acid-fast organisms have been isolated from sputums and urines, that guinea pigs are considered very susceptible to the tubercle bacillus, that the antiformin did not injure their acid-fast properties and is generally

considered not injurious to acid-fast tubercle bacilli,[16] and since the patients are not positively tuberculous clinically, it would appear that the organisms were probably saprophytes. The action of the organisms towards Fonte's method was a border-line one. In view of the work of Spengler[17] and also of Much[18] on non-acid-fast tubercle bacilli, one can not use this border-line reaction as evidence one way or the other.

It is hoped to continue this work and determine the relative frequency of occurrence of saprophytic acid-fast organisms in urine and sputums and to further check up the value of Fonte's and other promising methods of differentiation. If non-acid-fast or partially acid-fast tubercle bacilli were very commonly met with in urines and sputums from tuberculous patients it would be quite evident that no staining method based upon acid-fastness would be efficient, but there has not been much evidence brought forward to show anything but the scarcity of these non-acid-fast strains. The work of Wherry[19] indicates that this cause of acid-proofness of parasitic organisms is different from that of saprophytes. As to the acid-fast properties of intermediate organisms with a very low grade of virulence nothing has been reported along the line of Wherry's investigation. The many conflicting results which have led to the development of so many differential staining methods, added to conflicting opinions of the acid-proofness of different members of this group, suggests a wide variation in acid-proofness among the saprophytic members of the acid-fast group, at least. The work of this paper further confirms this fact. An explanation for the decolorization by Fonte's method of pure cultures of the tubercle bacillus, as well as other acid-fast organisms as reported in this paper, is that the tubercle bacillus, as well as the others, was growing saprophytically, hence its acid-proofness differed materially from that of the parasitic tubercle bacilli of the twenty-nine positive clinical cases of tuberculosis. These laboratory strains of the tubercle bacillus have also lost their pathogenicity. It may be that the groups are so closely related as to offer insurmountable obstacles to their absolute and complete differentiation. A method having a very high percentage of efficiency would be very valuable and desirable.

CONCLUSIONS.

1. That there is great variation in the acid-proofness of different strains of *B. smegmatis.*

2. That even in positive sputums there is some tinctorial difference of the tubercle bacillus toward Fonte's stain, whereas with the other methods very little if any tinctorial variations were observed.

3. That Gabbet's, Ziehl-Neelsen's, Pappenheim's, and Bunge and Trantenroth's methods are not at all reliable as a means of differentiating the tubercle bacillus from the rest of the acid-fast group.

4. That Fonte's method seems to be much superior to the other methods, but not entirely reliable in urine, and even in sputum examinations. The percentage of error can only be determined by much more extensive work.

5. That the error of all of these methods seems to be that of giving too many positive results.

6. That Fonte's method might prove quite serviceable in urine and feces examinations when used along with the clinical symptoms, cellular content and chemical tests. In case any of the latter are negative, animal inoculation should be resorted to. It must be remembered that none of the above staining methods can be relied upon alone. Probably few errors are made in sputum examination, on the positive side, by any of the routine methods, because clinical symptoms are usually pronounced before the sputum is examined. Perhaps many more sputums are called negative that should be positive than the reverse. However, there is at least some chance for error on the positive side in sputum examinations. With urine and feces the great problem confronting the bacteriologist is to rule out the saprophytes.

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On a Collection of Fossil Vertebrates Made by Dr. F. W. Cragin in the Equus Beds of Kansas.*

BY OLIVER P. HAY.

IN the sixth volume of the Colorado College Studies, on pages 53 and 54, issued at Colorado Springs, Colo., March, 1896, Dr. F. W. Cragin made a brief report on some vertebrate fossils which he had discovered in 1891, in Meade and Clark counties, Kansas. Later Doctor Cragin became interested in other studies and did not come back to these fossils. These now form a part of the collection of Colorado College, and, through the kindness of the honorary director of the museum, Mr. Edward R. Warren, the writer has been permitted to bring them to Washington and to study them.

A portion of the fossils were found near the head of Bluff creek, in the western part of Clark county, east of Minneola, and the others along Spring creek, a tributary of Crooked creek, about four miles southwest of Meade, in Meade county. In this region Doctor Cragin discovered three terranes, the lowest of which, varying from ten to forty feet in thickness, he named the Meade gravels. He recognized that these gravels belonged to what has been called the Equus beds. From them he reported *Elephas imperator* (?), *Megalonyx leidyi*, *Equus complicatus*, *E. curvidens*, and *Auchenia huerfanensis*.

Overlying the Meade gravels there was found a bed of volcanic ash which reached a thickness of thirteen feet. This contained few fossils. It was named the Pearlette. Above this ash bed were found marls, to which was applied the name Kingsdown. In that region the marls were apparently not less than 100 feet thick. Only *Elephas* was reported from them.

All of the materials of the collection made by Cragin which have been studied by the writer belong to the lowest terrane, the

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Meade gravels. The following species have been determined, of which two are new:

Testudo equicomes, new species.
Mylodon harlani Owen.
Hipparion cragini, new species.
Equus complicatus Leidy.
E. leidyi Hay.
Camelops huerfanensis (Cragin).
Canis occidentalis ? Richardson.
A large undetermined felid.

Testudo equicomes, new species.

In the Cragin collection made on Spring creek in Meade county there are eight fragments of bones which belonged to species of the genus *Testudo*. It is quite certain that three or four species are indicated, but only two of the fragments can be assigned to the same individual or species. To these the name *Testudo equicomes* is given. The other pieces of bone can not be assigned to their species.

The two bones which quite certainly belonged to the same individual are the right epiplastron and the left hypoplastron. The epiplastron (pl. I, figs. 1, 2) has a projecting and much thickened beak. The distance from the midline in front to the point on the free border where the bone joined the hypoplastron is 68 mm. The width of the bone at the middle of its length is 30 mm. The length of the beak, measured on its upper surface and at the midline, is 35 mm.; and at its rear it is 27 mm. thick. The whole free border of the bone is acute. From this border the hinder half of the bone thickens until, at a short distance behind the beak, it reaches a thickness of 11 mm.

The hinder and inner borders of the hypoplastron (pl. I, fig. 3) are missing, so that the bone present reaches neither the midline nor the hypoplastron. From the anterior end of its free border to the axillary notch is a distance of 30 mm.

Figure 1 of plate III represents an attempt to restore the anterior portion of the plastron from the two fragments described above. The lobe appears to have been relatively short and broad. From one axillary notch to the other was apparently 160 mm. From the middle of the line joining these notches to the front of the beak was 66 mm. The entoplastron appears to have been unusually wide, apparently about 80 mm. How it ended behind is conjectural. From the outer edge of one hypoplastron, at the bridge, to that of the other was about 200 mm. Basing the esti-

mates on this width it is concluded that the carapace had a length of about 340 mm. and a width of 290 mm.

As will be observed on the figures, the gular scutes extended backward on the entoplastron. The humeropectoral sulcus bends backward and again forward as it crosses the hypoplastron. This forward curve makes it probable that the sulcus crossed the hinder end of the entoplastron, but this is not certain. Another sulcus just outside of the axillary notch cut off an axillary scute.

This tortoise is quite distinct from *Gopherus polyphemus*. It is probable that a very large species, *T. crassiscutata*, inhabited Kansas and the region further south during the early Pleistocene, inasmuch as it occurs in Texas; but this was far larger, and the bones described above give no indication of having been those of a young animal.

Mylodon harlani Owen.

In the collection are three teeth of a *Mylodon* which seem to belong to the species named above. Cragin reported these as belonging to *Megalonyx*; but they certainly do not belong to that genus. They were found four miles southwest of Meade, Kan.

These teeth are identified as the left first and third upper teeth and the right first of the lower jaw. They are all damaged somewhat and parts have been lost at some time since exhumation.

The first upper tooth is shown on plate I, figure 4; and a section is shown on the plate (pl. III, fig. 2). The present length of the tooth, measured along the greater curve, is 120 mm. Originally it was somewhat, but not greatly, longer. It will be observed that it curved considerably in passing downward and forward from the bottom of the socket. In section the tooth is broadly oval, with the inner face somewhat flattened. The anteroposterior diameter is 21 mm.; the transverse, 17 mm. It will be seen that this resembles closely the section of the first tooth given by Cope (Proc. Amer. Philos. Soc., vol. XXXIV, p. 459, pl. X, fig.1,*a*) and reproduced by the present writer (Geol. Surv. Iowa, vol. XXIII, p. 134, fig. 33). The grinding surface is concave from front to rear and it slopes somewhat downward from the outer side.

The third upper tooth is here shown in section (pl. III, fig. 3). The present height of the tooth is 70 mm., but it was originally higher. The greatest diameter is 36 mm., the width across the anterior lobe, 27 mm. The hinder lobe is 13 mm. thick. The grinding surface shows two planes of wear, one on the broad an-

terior lobe, the other on the hinder lobe. The two meet at the place of union of the two lobes, making an angle of about 135°. This tooth appears to resemble closely the third upper tooth of G. M. Allen's *Mylodon garmani* (Mem. Mus. Comp. Zool., vol. XL, pl. 2, fig. 3) rather more than that represented by Cope (op. cit.); but the latter tooth was not complete, and was pretty certainly incorrectly restored.

The first lower tooth is here shown from behind (pl. I, fig. 5) to illustrate its curvature, and in section (pl. III, fig. 4). The height in a straight line is 90 mm. The anteroposterior diameter is 23 mm.; the transverse 16 mm. The groove along the inner face is deeper than in the section given by Cope. Of this tooth in *Mylodon garmani*, Allen says that the inner side is nearly flat. As in the tooth just referred to, there are two planes of wear, an anterior and a posterior.

Hipparion cragini, new species.

In the collection made by Doctor Cragin there is an upper molar or premolar which seems to belong to a hitherto undescribed species. Accompanying the specimen is a note made by Doctor Cragin which reads as follows:

"Upper part of Bluff Cr., Clark Co., east of Minneola (Thomas ranch), in Pleistocene deposits bearing *Elephas columbi* and *Equus curvidens*. Can this have been derived from the Loup Fork? Latter occurs, but further east."

It is, of course, possible that the tooth was originally left in deposits preceding the Pleistocene. However, it presents no signs of being water-worn, rolled or weathered. It is stained just as are teeth of *Equus* from the same beds.

It is not yet certain that species of *Hipparion* continued on into the Pleistocene; but there are some indications that they did. A tooth of *Hipparion*, referred by the writer with doubt to *Neohipparion gratum* (Geol. Surv. Iowa, vol. XXIII, pl. IX, figs. 1, 2), was found in what is supposed to be Aftonian gravels, at Rockport, Mo. Other remains were discovered in Aftonian gravels near Thayer, Iowa. The occurrence of the tooth here described in Pleistocene deposits in Kansas supports the view that the genus did not become extinct at the close of the Tertiary.

The crown (pl. I, figs. 6, 7) has now a height of 38 mm. on the outer face. The length of the grinding surface is 17 mm.; the width, 17 mm. The protocone has a fore-and-aft diameter of 6.5 mm. At a distance of 25 mm. above the grinding surface the fore-

and-aft diameter of the crown is 16 mm.; the side-to-side diameter, 17.5.

The outer styles are strongly developed, standing out boldly from the face of the tooth. Near the grinding surface these styles have a diameter of 2.5 mm., but toward the root the median widens to 4 mm. The anterior one also widens slightly.

The lakes have the enamel surrounding them only moderately complicated. In the anterior lake there is a deep infold at the hinder inner angle, and a smaller one in the hinder border. In the hinder lake there are a shallow fold and another rather deep one in the anterior border and a moderate one in the hinder border.

The oval protocone is detached from the other columns of the tooth, but lies close to them. A small loop at the head of the hinder inner valley comes nearly into contact with the enamel of the protocone. The inner face of the protocone is very slightly convex.

It is possible that the *Hipparion* teeth mentioned above as being found in the Pleistocene of Missouri and Iowa belong to this species; but while the crown of the Kansas specimen is very straight, that of the Missouri tooth is considerably curved. The protocone of the latter is considerably smaller than is the former.

This tooth differs from those of *H. gratum*, figured by Cope (Proc. Philos. Soc., vol. XXVI, figs. 16, 17) in being much straighter. From these and most of those figured by Leidy (Jour. Phila. Acad., vol. VII, 1869, pl. XVIII, figs. 25-30) the Kansas tooth differs in having the enamel somewhat more simple in its arrangement.

Equus complicatus Leidy.

In the Cragin collection there are a few teeth which are here referred to this species. Of these there are one upper right premolar and five lower cheek teeth. They were found on Spring creek, near Meade. The upper premolar, the third or the fourth, has a height of 80 mm., a length of 33 mm., and a width of 32 mm. The protocone is 17 mm. wide. There is a deep reëntrant loop at the head of the postprotoconal valley, and the enamel of the lakes is considerably complicated.

Three of the lower teeth appear to have belonged to the same animal. These are the two hinder premolars and the first molar (pl. II, fig. 1). The following are the measurements:

Measurements of lower teeth in millimeters.

Tooth.	Height.	Length.	Width.
Pm_3	58	30	17
Pm_4	65	29	17
M_1	56	25.5	15

The enamel of these lower teeth shows little plication of the enamel, and in that respect they are different from those which are in this paper identified as *Equus leidyi*. These teeth are somewhat smaller than might be expected; however, they are all, and especially the molar, worn down to where the length is somewhat diminished.

Equus leidyi Hay.

In the collection there is a part of the left maxilla, which contains the last premolar and all the molars (pl. II, fig. 2). The specimen was found in the Meade gravels, at the head of Bluff creek, in Clark county. It was regarded by Doctor Cragin as *Equus curvidens* Owen; but the teeth of that South American species have the enamel less complicated and the styles stand out less prominently from the outer face.

The teeth of the Bluff creek specimen are those of a horse probably hardly four years old. The last premolar had been but slightly abraded; the hindermost molar had not yet been cut. The first and second molars are only moderately worn.

The maxilla reaches the midline, thus presenting one-half of the width of the palate, which had, between the first molars, a width of 75 mm. The posterior palatine foramen opened opposite the front half of the second molar. The maxillary ridge continued forward to the middle of the last premolar.

The last premolar is slightly curved; the molars are much curved. As one follows them upward from the grinding surface they bend both backward and inward (pl. II, figs. 3, 4). The following measurements are afforded. The length and the width are taken somewhat above the grinding surface. The dimensions of the last molar are of less importance than those of the other teeth.

Measurements of the cheek-teeth in millimeters.

Tooth.	Height.	Length.	Width.	Protocone.
Pm^3	92	28	29	12
M^1	90	27	27	12
M^2	97	27	26	12
M^3	70	26	24	....

The styles stand out prominently on the outer faces of the teeth. As usual, the anterior one of the premolar is broader than in the molars, but there is no defined groove running along it. The protocone is slightly concave on its inner face. The enamel of the worn teeth, especially that of the first molar, is considerably complicated. There is a notch in the front wall of the anterior lake, while in the hinder wall of the posterior lake there is a deep infold and two or three shallow ones. The adjacent borders of the two lakes have each a very deep infold and two or three shallower ones. In the head of the postprotoconal valley there is a rather deep reëntrant loop.

Besides the tooth described above there are seven loose upper premolars and molars, which were found along Spring creek, four miles southwest of Meade, Kan. I am not sure that the position of certain of the teeth has been correctly determined. In some cases, as Nos. 2 and 6 of the list below, the anterior style is narrow, indicating that the tooth is a molar, but it is traversed from end to end by a shallow groove. In another case, No. 1, the style is broad and without groove. The following are the measurements. It is to be understood that here, as in all other cases, the height of the tooth is given merely to show the amount of wear it has suffered.

Measurements of teeth in millimeters.

Tooth.	Position.	Height.	Length.	Width.	Protocone.
1	Pm^4	80	26	27	12
2	$Pm^{4?}$	90	24	22	13.5
3	$M^{1?}$	60	23	24	15
4	$M^{1\text{ or }2}$	75	24	26	12
5	$M^{1\text{ or }2}$	65	26	24	15
6	$M^{1?}$	85	24	24	..
7	Pm^4	62	27	27	12
8	Pm^4	58	28	28	12

In the true molars of *E. leidyi* there appears to be a strong tendency to retain the reëntrant loop at the head of the post-protoconal valley.

Among the lower teeth of horses collected on Spring creek are three premolars (pl. III, fig. 5) which appear to have belonged in the left side of the same jaw; and three molars (pl. III, fig. 6) which apparently belonged in the right side of the jaw of the same individual as that which possessed the premolars, or of another individual of the same age. The horses, if more than one, were young, as will be seen from the height of the various teeth.

Measurements of lower teeth in millimeters.

Tooth.	Height.	Length.	Width.
Pm_2	65	28	13
Pm_3	85	28.5	16.5
Pm_4	88	27	15
M_1	78	25	13
M_2	..	29	15
M_3	60	30	12.5

The premolars are curved so as to be slightly convex on the outer face; the first molar is somewhat convex on the inner face and quite strongly convex on the front border. As will be seen from figure 5, the enamel of the premolars is much crinkled; that of the molars somewhat less so. Attention is called to the fact that the length of the grinding face of premolar 2 is not greater than of the next one.

Both in complication of the enamel and in length and width of the grinding surface these teeth resemble closely the teeth from the region about Charleston, S. C., which have been referred to *E. leidyi.*

In size the upper teeth above described agree closely with those forming the type of *Equus excelsus* Leidy. On close comparison it is seen that the styles on the outer face of the teeth of *E. excelsus* stand out more boldly and the intervening channels are deeper and more concave. The enamel of the lakes is far less complicated than in the teeth of the specimens collected by Cragin. That this condition is not due to the greater degree of attrition of the former is shown by the fact that some of the teeth of the Cragin collection are still more worn than those of the type of *E. excelsus,* and they still preserve the deep notches and plication of the enamel. In the type of *E. excelsus* the protocone is much longer than in most of the teeth referred to *E. leidyi.* While not too much importance can be attached to this fact, it must be considered. It seems to the writer that the Kansas specimens certainly do not belong to *Equus excelsus.*

Besides the equine materials above described, Doctor Cragin found on Spring creek a median metacarpal. This bone has a length of 225 mm. along the outer border. The width at the upper end is 46 mm.; at the middle of the length, 32 mm.; across the lower articular surface, 39 mm. The bone is very hard and heavy. It has been, at some stage in its history, much weathered, and it is cracked longitudinally. From the same place is another metacarpal nearly identical in dimensions but differently fossilized. Its length along the outer border is 216 mm.; width at the upper end, 46 mm.; at the middle of the length, 31 mm.; across

the lower articular surface, 41.5 mm. A third metacarpal from the same place is larger. The length is 232 mm.; width at the upper end 51.5 mm.; at the middle of the length, 33 mm.; across the lower articular surface 45 mm.

It seems that two species are indicated here; the latter bone being possibly that of *Equus complicatus*, the other two those of *E. leidyi*.

Besides these there are some phalanges, but none that bore hoofs. There are also two astragali. At least two species of horses are indicated in the phalanges and the astragali.

There are in the collection also four moderately worn incisors.

Camelops huerfanensis (Cragin).

Among the fossils collected on Spring creek are several teeth which the writer can not distinguish from those of the type of Cragin's *Camelops huerfanensis*, and it was to this species that Cragin himself referred them. These teeth consist of nine incisors, four canines, three upper second molars, three lower second molars, two lower third molars, two upper milk-molars, and three lower third milk-molars.

The incisors do not differ from those of specimens found at Minidoka, Idaho (Proc. U. S. Nat. Mus., vol. 46, p. 273, pl. 26, fig. 2). A mature canine, probably of the upper jaw, has the crown bent at right angles with the root and furnished with sharp front and rear edges, as in the lama. Another and stouter canine is somewhat less abruptly bent.

The least worn second upper molar has a height of 75 mm., a length of 50 mm. on the outer face at the grinding surface, and a length of 45 mm. at a point two-thirds the distance to the root. At the base the width of the anterior lobe is 28 mm., of the posterior 26 mm.

A right second lower molar, slightly worn, has a height of 70 mm. (pl. II, fig. 5). Its length at the grinding surface is 47 mm.; at two-thirds the way to the root, 40 mm. The width at the base is 19 mm. There is a well-defined style on the front of the inner face and another on its rear. The two lower last molars furnish the following measurements:

Measurements of hindermost lower molars in millimeters.

	No. 1.	No. 2.
Height	70	70
Length near grinding surface	56	62
Length near the root	60	67
Width of front lobe near base	20	23

No. 2 of the preceding table has a quite thick deposit of cement; that of No. 1 has been dissolved off. A second molar (M_2), which belongs with No. 2, has also a deposit of cement.

The two upper milk-molars are each worn only slightly on its front lobe. One (pl. I, fig. 8) has the anterior face broken off, but it was evidently somewhat smaller than the other tooth. Both have prominent external styles, front, median and posterior. The edges of the anterior and median are directed pretty strongly forward. The middle of the outer face of each lobe forms a prominent rounded ridge.

Measurements of upper milk-molars in millimeters.

Tooth.	Height.	Length of summit.	Length near root.	Width at base.
1	43	45±	32	23
2	45	48	32	23

Of the three lower third milk-molars, two belong to the left side, one to the right. One of those of the left side is in a fragment of the jaw (pl. II, fig. 6), and it seems to have belonged to the same individual as the tooth of the right side. Each has a little accessory column, 15 mm. high, just behind the median style of the inner face. This column is absent on the other tooth of the left side. The height of the milk-molar figured is 43 mm.; the length at the summit, 54 mm.; near the base, 40 mm.; width at the base, 16 mm.

On Spring creek there were obtained two upper phalanges of camels. They pertained probably to the front limbs. The following measurements are given to aid in making comparisons with other like materials.

Measurements of phalanges in millimeters.

	No. 1.	No. 2.
Length along outer border	130	115
Width across the upper articulatory surface	49	....
Fore-and-aft diameter at middle of length	29.5	24.5
Side-to-side diameter at middle of length	23	21
Width across lower articular surface	38	32

Canis occidentalis ? Richardson.

In the collection is an injured lower right first molar of a wolf which was found on Spring creek, near Meade. This tooth is referred with some doubt to the species above mentioned. Unfortunately, the outer face of the principal cone and that of the anterior cone have been split off and lost; also the front border of the anterior cone is missing. Comparison of the tooth has been

made with the corresponding one of *Canis dirus*, from Rancho La Brea, California; of *C. occidentalis*, from Alaska; and of *C. gigas*, from Oregon. The following measurements have been taken:

Measurements in millimeters.

	Length of tooth.	Width of talon to length of tooth.	Width of principal cone to length of tooth.
Kansas specimen	32.3	37.1:100	38.7:100
La Brea specimen	36.5	35.6:100	43.8:100
Alaska specimen	32.0	35.3:100	40.6:100
Oregon specimen	28.0	32.1:100	44.6:100

It will be observed that, as regards size, the Kansas tooth is much nearer to that of *C. occidentalis* than to any of the others. The tooth differs from all of the other teeth in the width of the talon. The metaconid is somewhat more strongly developed than in *C. occidentalis*. It is possible that this tooth represents a distinct species, but the evidence is not sufficient to establish this.

Undetermined Felid.

In the collection made on Spring creek, about four miles southwest of Meade Center, Kan., are found some remains of a very large cat-like animal. These consist of the left second metacarpal; the proximal three-fourths of the right fifth metacarpal; the right calcaneum; the proximal two-thirds of the right fourth metatarsal; a proximal phalange of probably the fourth digit of the pes; and the distal half of another proximal pedal phalange. There is no certain evidence that any two of the bones were found together, but it seems probable that all belonged to one individual. They shall here be so considered. All these parts indicate an animal somewhat larger than the African lion.

The second metacarpal, as the other bones, is compared with that of a lioness captured in Africa by the Roosevelt party.

Measurements of second metacarpals in millimeters.

Dimensions Taken.	Fossil felid.	*Felis leo.*	Ratio of fossil to *Felis leo* taken as 100.
Total length of bone in straight line	111	94	118
Height of proximal end	32.5	25	130
Width of proximal end	21	19	110
Side-to-side diameter at middle of length	16	12	133
Vertical diameter at middle of length	16	13.5	118
Side-to-side diameter above lower articular surface	23	19	121

The distal end of the fifth metacarpal is broken off, as well as a part of the proximal articulation. The total length of the fragment is 82 mm. The greatest width of the proximal end is 27 mm.; of that of the lioness, 22 mm.

The calcaneum is slightly injured at both ends. The following are the measurements of this calcaneum and that of the lioness:

Measurements of calcanea in millimeters.

DIMENSIONS TAKEN.	Fossil felid.	*Felis leo.*	Ratio of fossil to *Felis leo* taken as 100.
Total length of bone on outer face	123	90	137
Height of surface for cuboid	31	22	141
Greatest height at surface for astragalus	50	39	128

The calcaneum of another lion is 106 mm. long.

The fourth metatarsal lacks the distal end. The greatest depth of the proximal end is 25 mm.; of that of the lioness, 21.5 mm.

The complete first phalange mentioned is 52 mm. long, measured on the upper surface and at the middle of the width. That of the third digit of the hind foot of the lioness is 41 mm. That of the fossil has the lower face flat or concave from side to side; in the lioness this face is convex from side to side.

DESCRIPTION OF PLATES.

PLATE I.

FIGS. 1-3. *Testudo equicomes.* Parts of plastron. Type. × 1. *1*, Right epiplastron, seen from below. *2*, Right epiplastron, showing median suture. *3*, Left hyoplastron, seen from below.

FIGS. 4, 5. *Mylodon harlani.* Teeth. × 2-3. *4*, Left front upper tooth, seen from right, or inner, side. *5*, Right first lower tooth, seen from behind.

FIGS. 6, 7. *Hipparion cragini.* Two views of a tooth of the right side. Type. × 1. *6*, Tooth seen from right, or outer, side. *7*, View of the grinding surface.

FIG. 8. *Camelops huerfanensis.* Upper left milk-molar, seen from left, or outer, side. × 2-3.

PLATE II.

FIG. 1. *Equus complicatus.* Lower left cheek-teeth, pm_3, pm_4 and m_1.

FIGS. 2-4. *Equus leidyi.* Upper jaw and teeth. × 2-3. *2*, Left jaw and four teeth, seen from below. *3*, First molar, seen from left, or outer, side. *4*, First molar, seen from in front.

FIGS. 5, 6. *Camelops huerfanensis.* Teeth. × 2-3. *5*, Lower right second molar, seen from right, or outer, side. *6*, Lower right second milk-molar, seen from left, or inner, side.

PLATE III.

FIG. 1. *Testudo equicomes.* Plan of front of plastron of type. × 1-3.

FIGS. 2-4. *Mylodon harlani.* Sections of teeth. × 1. *2*, Section of first upper tooth. *3*, Section of third upper tooth. *4*, Section of first lower tooth. In the case of figures 2 and 4 the fronts of the teeth are above. In figs. 2 and 4 the inner faces of the teeth are toward the left; in figure 3 it is toward the right.

FIGS. 5, 6. *Equus leidyi.* Grinding surface of lower premolars and molars, × 1. *5*, Left premolars. *6*, Right molars.

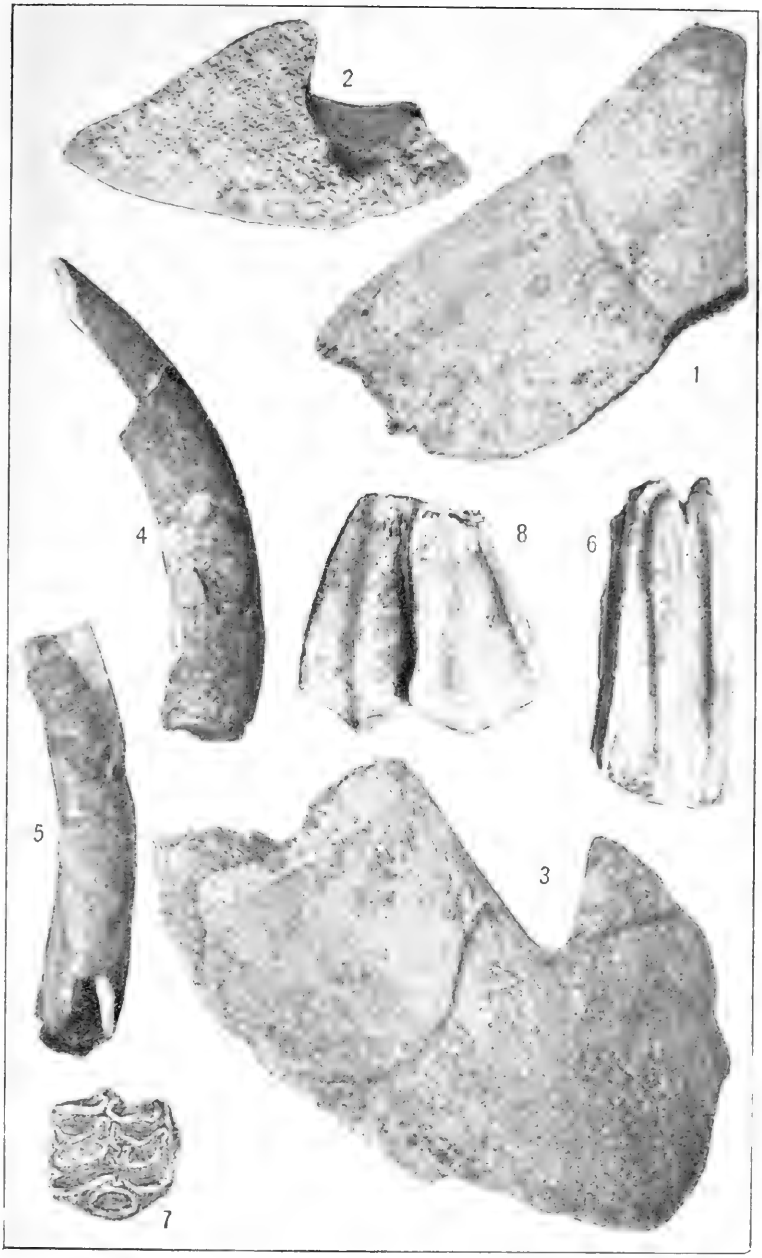
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PLATE II.

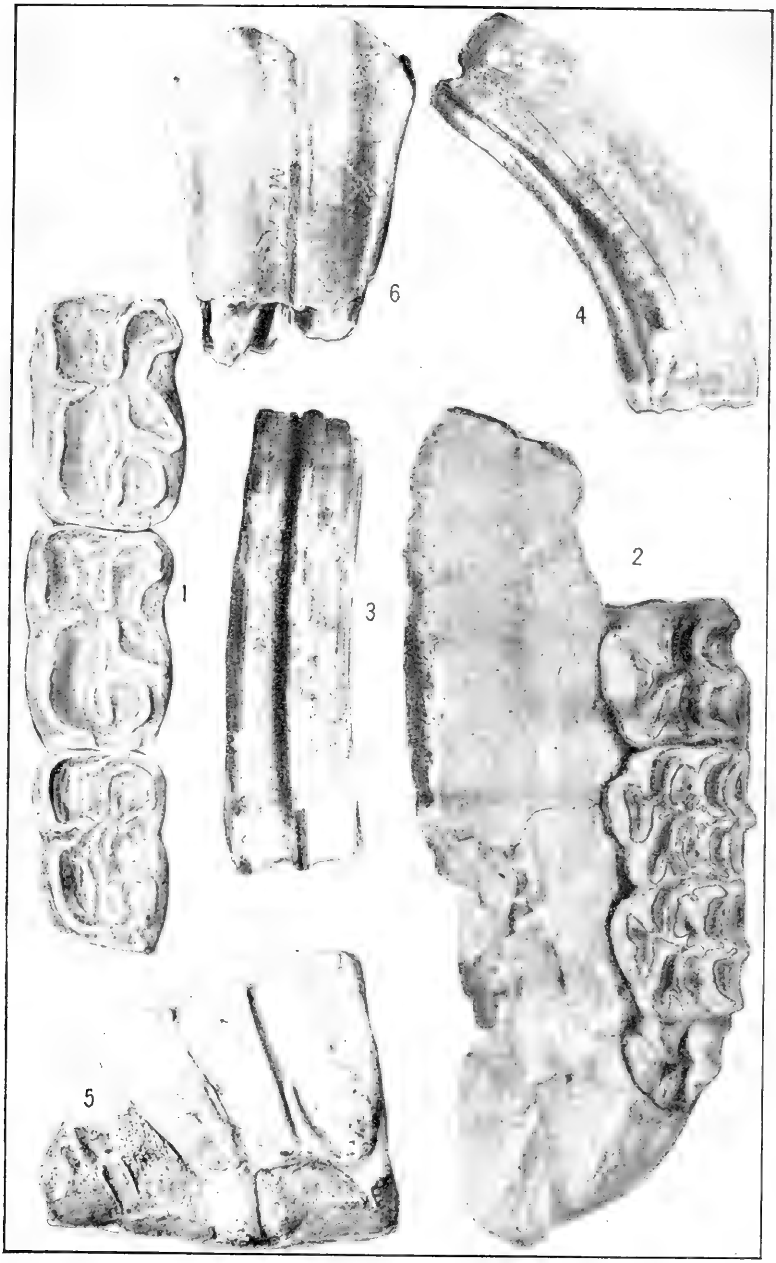
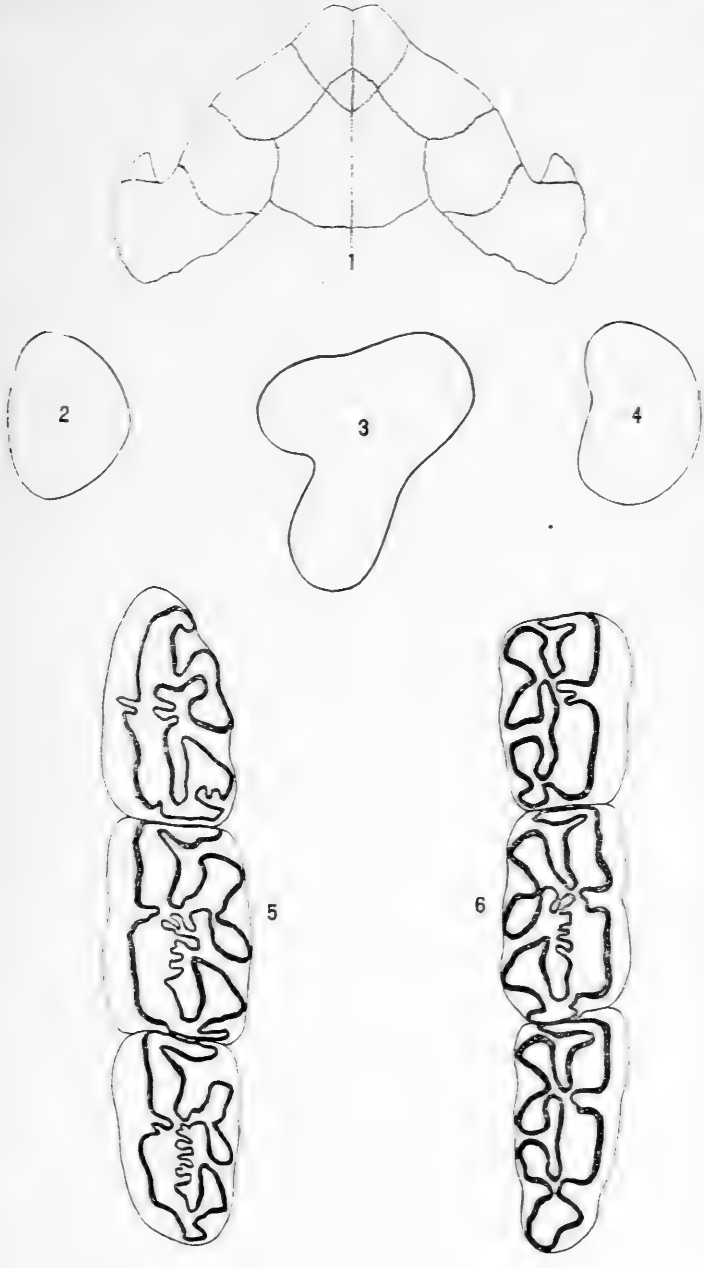


PLATE III.



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Ogmodirus martinii, a New Plesiosaur from the Cretaceous of Kansas.

BY S. W. WILLISTON,

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THERE have been recorded from the Cretaceous deposits of Kansas five genera and sixteen species of plesiosaurs, as follows:

From the Comanche (in the restricted sense of the term), two species referred provisionally to *Plesiosaurus;* from the Benton, two species of *Trinacromerum* (including the genotype), one of *Brachauchenius,* the genotype, and one of *Elasmosaurus;* from the Niobrara, five species of *Elasmosaurus,* two of *Polycotylus,* including the genotype, and one of *Trinacromerum;* from the Fort Pierre, the genotype of *Elasmosaurus,* and one species referred provisionally to *Plesiosaurus.* Of the above, doubtless all those referred to *Plesiosaurus* belong to other as yet unrecognized genera; and in much probability several of those referred to *Elasmosaurus* from the Benton and Niobrara will be found eventually to pertain to other genera. One of these, especially *E. ischiadicus* Will., quite surely does not belong in that genus and may belong in the present genus. It was originally described as a problematical species of *Polycotylus* because of its short cervical vertebræ, but later quite surely eliminated from that genus because of its short ischia. For the present it may find a location in the following genus.

The present genus, *Ogmodirus,* from the Cretaceous of Cloud county, Kansas, is of peculiar interest in presenting certain intermediate characters between the Elasmosauridæ and Plesiosauridæ, the two distinctive families of long-necked plesiosaurs. The two families differ, aside from the skull, especially in the

structure of the pectoral girdle. The characters of the genus *Elasmosaurus* have been given by the senior author[1] as follows:

"Symphysis of mandibles short; teeth markedly anisodont. Neck with seventy-six true cervical vertebræ and three pectorals, the centra increasing in length to the fifty-eighth, and then decreasing in length to the dorsals, thence nearly uniform in length throughout the dorsal region. Posterior cervicals and dorsals much wider than high, and wider than long; spines wide and not high; zygapophyses weak. Pectoral girdle with large scapulæ meeting each other in the middle line. No interclavicular foramen; coracoids broadly separated posterior to the interglenoid thickening, their posterior ends not much dilated. Cervical ribs single headed. Ischia short."

Of these characters the number of cervicals is doubtless a specific character; the species *E. serpentinus* has but sixty cervicals. The elongation of the posterior cervicals is undoubtedly a real generic character, and is common to various species. The approximation of the scapulæ and absence of the interclavicular foramen, and also, in much probability, of the interclavicle, may or may not be of family value. The European forms referred to this family do not have, so far as published, the broad separation of the coracoids posteriorly. It is very probable that, when the skulls have been more attentively compared, *Cryptocleidus* and its allies will be excluded from the family Elasmosauridæ.

That the present genus is distinct from *Elasmosaurus* is evident. Until its skull and pectoral girdle are known its position in the family is doubtful. The only other long-necked genus with which it can be compared is *Leurospondylus* Brown,[2] recently described. So far as the description and figures of that genus apply to the present material the two genera can not be distinguished.

The material upon which *Ogmodirus* is based is represented by the following parts: fifty-one consecutive cervical vertebræ, eighteen caudal vertebræ, humerus, femur, many carpal and phalangeal bones, the right ilium, a part of a pubis, and various fragments of ribs and neural spines. This material was collected in 1909 by Mr. C. Boyce in Cloud county, Kansas, associated with the remains of another plesiosaur, and presented by him to the University of Kansas. Its horizon is probably the Fort Hays limestone of the basal Niobrara, though possibly, but improbably, from the uppermost horizon of the Benton. The species has been named in honor of Mr. H. T. Martin, in appreciation of his long,

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1. Williston, S. W. 1906. North American Plesiosaurs: *Elasmosaurus, Cimoliasaurus* and *Polycotylus*. Amer. Journ. Sci., 4th ser., vol. xxi, No. 123, March, p. 225.

2. Brown, Barnum. 1913. A New Plesiosaur, *Leurospondylus*, from the Edmonton Cretaceous of Alberta. Bull. Amer. Mus. Natl. Hist., vol. xxxii, art. xl, pp. 605-615, figs. 1-7. December.

faithful and intelligent work in the Cretaceous deposits of Kansas for the University of Kansas.

The genus *Ogmodirus* (ὄγμος drawn out in a straight line and δειρή neck) has been defined as follows:[3]

Cervical vertebræ short, almost as wide as long, gradually increasing in size. The length and breadth are proportionate, as is indicated in the following table of measurements:

		Length.	Width.
Cervical vertebra	1	0.020 m.	0.030 m.
Cervical vertebra	6	0.023 m.	0.032 m.
Cervical vertebra	12	0.030 m.	0.038 m.
Cervical vertebra	20	0.034 m.	0.044 m.
Cervical vertebra	30	0.041 m.	0.052 m.
Cervical vertebra	40	0.045 m.	0.067 m.
Cervical vertebra	45	0.045 m.	0.067 m.
Cervical vertebra	51	0.046 m.	0.072 m.

Since there is nothing present of either the atlas or axis, the first cervical vertebra preserved must be at least the third of the series, possibly a later one. At any rate it is the first of the series preserved. No cervical ribs are preserved complete, though there are fragments of them. The rib facettes are present throughout the cervical series. (Fig. 1, text.) For a member of the Elasmosauridæ the neck is not extraordinarily long, containing probably about sixty vertebræ, and measuring about 2 meters. The paddles are not expansive, but short and thick, with the metacarpals and phalanges short and heavy.

The fore limb (plate II) has a complete length of 0.600 m., of which 0.152 m. belongs to the propodium, 0.050 m. to the mesopodium, 0.070 m. to the metapodium, and about 0.300 m. to the digital portion. This is making no allowance for the cartilage, ligaments and integument, which doubtless adds several millimeters to the length as given.

Cervical vertebræ. These centra are, as usual, nearly amphiplatyan. On the visceral surface they are, throughout the series, perforated by a pair of vascular foramina (plate IV, fig. 5), which have a diameter of 2 mm. On the fifteenth vertebra preserved this opening measures 6 mm. There are two articular surfaces for the articulation of the ribs (plate I). These articular surfaces gradually increase in size toward the dorsal region. On the third cervical they possess a length of 11 mm. and a breadth of 8 mm.; on the fifteenth a length of 18 mm. and a breadth of 14 mm. Superficially there appears over all the cervical centra many

3. Williston, S. W., and Moodie, Roy L. 1913. A New Plesiosaurian Genus from the Cretaceous of Kansas. Bull. Geol. Soc. Amer., vol. 24, No. 1, pp. 120, 121. March.

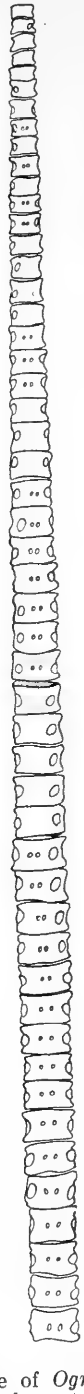


FIG. 1. The cervical vertebræ of *Ogmodirus martinii* drawn from the ventral side. The series is incomplete at both ends.

punctiform vascular pits and canals (plate IV, fig. 5), doubtless indicating a rich periosteal blood supply. The articular facttes for the neural arches are egg shaped, possessing a length of 31 mm. and a breadth of 15 mm. of the fifteenth vertebra. Between the articular facettes for the neural arch lies the shallow, hourglass-shaped canal for the spinal cord, or rather the meningeal canal. In the center of the canal occur two egg-shaped vascular pits. The centra are slightly constricted in the middle of the bone, although the visceral portion is larger than the neural portion, owing to the presence of the costal articulations.

The articular surfaces for the *neural spines* are identical in the most anterior and in the most posterior. They are oval in shape, with the central point most depressed. Between the depressions for the neural spines superiorly there are two nutrient foramina corresponding in position and undoubtedly in function to the ventral structures of the same.

The diapophysis stands out moderately; vertically elongate, apparently connected by a narrow surface upward on the arch. The lower extremity of the articular surface, however, reaches pretty well down on the ventrum.

Transverse diameter of the centrum	84
Vertical diameter of the centrum	78
Length	45–48

The better of the two dorsals is deeply cupped, circular in outline, with rather sharp rims, rather deeply concave on the sides and below and circular in cross section through middle. Vascular foramen situated high up on the sides, above the middle.

Length below	55
Length above	51
Transverse diameter	100
Vertical diameter	92

Only a few much water-worn fragments of spinous processes are preserved (plate IV, fig. 3); of the neural arch nothing is at hand. One of the best-preserved neural spines is deeply scarred by the teeth of some predaceous Cretaceous fish. The neural spine possesses a height of 85 mm. and a breadth of 31 mm. Outwardly the spine is smooth, the apex roughened for a cartilaginous tip, apparently indicating an immature animal.

The neural spines are relatively heavy, broad, and laterally flattened. Only fragments of them are preserved, but one of these fragments consists of a nearly complete spine. The tip was capped by a large amount of cartilage, another indication of the youthful

character of the individual. The edges are roughened for muscular attachment and the sides are smooth. The zygapophyses are rounded and saddle-shaped.

Measurements of Cervical Vertebræ.

(No. 441, University of Kansas Museum of Natural History.)

Length of most anterior vertebra preserved	20 mm.
Width of most anterior vertebra preserved	28 mm.
Height of most anterior vertebra preserved	17 mm.
Median width of neural canal	5 mm.
Length of the most posterior vertebra preserved	45 mm.
Width of same	70 mm.
Height of same	43 mm.

Measurements of Neural Spine.

(Possibly associated with the cervical vertebræ.)

Height of single spine preserved	85 mm.
Dorsal width	30 mm.
Ventral width	36 mm.

Among the material brought in by Mr. Boyce there was a string of eighteen caudal vertebræ which are possibly to be associated in this species. We will at least place them there provisionally until such a time as further information will permit their exact identification. They consist of four pygals and fourteen caudals. The pygals differ in form from the most posterior caudals, but have essentially the structure exhibited by the cervicals, *i. e.*, short, heavy, depressed, with lateral rib articulations. The most anterior pygal differs from the cervicals in being shorter, with the neurocentral articular surfaces wider apart, and the rib articular surfaces larger, the reduction in size of the nutrient foramina and the more marked amphicœlous character of the centra. This will sufficiently characterize the pygals. The caudals differ from the pygals in a further reduction along these same lines.

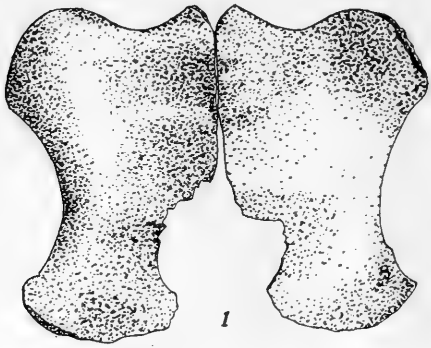
Measurements of the Pygals and Caudals.

Length of most anterior pygal	31 mm.
Width of same	60 mm.
Height of same	36 mm.
Diameter of neural canal	15 mm.
Length of rib articular surfaces	20 mm.
Width of rib articular surfaces	18 mm.
Length of most posterior caudal	23 mm.
Width of same	54 mm.
Height of same	38 mm.
Diameter of neural canal	9 mm.

The neurocentral articular surfaces are divided into two portions, separated by the rib articular surface. The most anterior of the pygals indicates a sacral intumescence for the hind limbs. Just what its size in proportion to the brain may be would be an interesting matter. The intumescence extends through several of the vertebræ and indicates an active use of the limbs as propelling organs. The most posterior cervical preserved has no indication of such an intumescence, so we must conclude that the neck is still incompletely represented even with the fifty-one vertebræ, and may have included six or eight more. Certainly none of the vertebræ described above as cervical belong to the dorsal series.

Forelimb. There was enough material present, although badly scattered, which seemed to belong to a single member, to reconstruct (plate II) a paddle which has been referred to the left side. This limb has a total length of 0.600 m., of which 0.152 m. belongs to the humerus, 0.050 m. to the radius and ulna, 0.070 m. to the carpals, and perhaps 0.300 m. to the digital division, although the distal phalanges are lost. The breadth of the limb at the level of the radius is 0.150 m., at the carpus 0.130 m. and at the third phalangeal row 0.120 m.

FIG. 2. The humerus of *Ogmodirus martinii* from the ventral side.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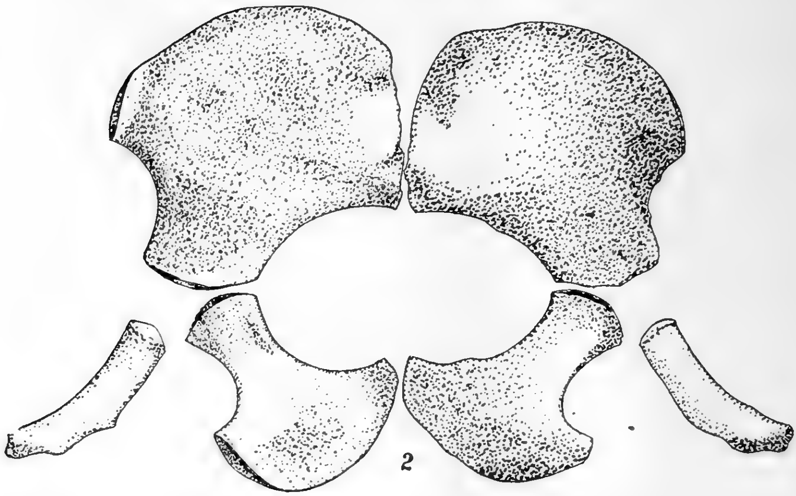
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Fig. 3. (1) The coracoids of *Leurospondylus*. After Brown.
(2) The pelvic girdle of *Leurospondylus*. After Brown.
These figures are inserted here for the sake of completeness. The form described by Brown is very similar to *Ogmodirus*, and the parts of the skeleton which he figured and described are lacking in the present form.

The *humerus* is associated with the paddle remains provisionally. They were scattered and dissociated when the specimen was brought to the museum. It is possible that portions of two paddles are represented. The element is well characterized in the figure (plate III, fig. 1, and text fig. 2). It is short, heavy and thick, extremely so for a plesiosaur. Its lower surface is flattened and relatively smooth, with a slight tuberculation near the proximal end for muscular attachment. The ends are marked with pits and cones (plate III, figs. 2 and 4), resembling minature volcanoes. These pits and mounds doubtless indicate the fact of

emigration of the osteoblastic tissue from the medullary canal, which in this species is highly developed. The mounds correspond to the points of entrance of the *Canalis ossificans perforans*, which in mammals transmit the osteoblasts from the medullary portion of the diaphysis into the epiphysis. The element is regarded as a humerus simply on account of its shortness, since it has heretofore been an invariable rule among the plesiosaurs that the shorter propodial is the humerus.

The humerus is remarkably short and broad, thickened at the proximal end, so that at this point it shows a rounded outline in cross section. The element gradually expands distally, especially toward the median plane, so that finally the distal end appears partly separated by an indentation. On the upper surface the bone has been distinctly marked on the radial edge (plate III, fig. 1) by the teeth of some predaceous fish or reptile, inflicted shortly after the death of the animal. This is not a rare occurrence among Kansas Cretaceous fossils, and indicates that some of the Cretaceous vertebrates were carrion feeders.

There are no well-developed facettes on the ends of the humerus such as is so common among other plesiosaurian species.

Measurements of Humerus.

Length	0.152 m.
Width at proximal end	0.070 m.
Width at middle	0.071 m.
Width at distal end	0.112 m.
Thickness at proximal end	0.050 m.
Thickness at distal end	0.036 m.

The *radius* and *ulna* are flattened, rounded plates, with broad peripheral surfaces for articular cartilage. The ulna is much smaller than the radius and is more nearly rounded. The radius is elongate transversely, with the ventral surface concave and marked by several vascular pits. (Plate II.)

Measurements of Ulna.

Greatest breadth	47 mm.
Least breadth	42 mm.
Greatest thickness	21 mm.

Measurements of Radius.

Greatest breadth	70 mm.
Least breadth	52 mm.
Greatest thickness	25 mm.

The *carpals* (plate II) are of the same character as the radius and ulna. They can only be distinguished by size. The largest

of the carpals is regarded as the centrale. It is in the form of a rounded triangle. Its measurements are:

Greatest breadth	50 mm.
Least breadth	44 mm.
Thickness	20 mm.

The smallest carpal element is rounded, measuring 27 mm. in diameter.

The *phalanges* (plate II) vary in shape. There are twenty-three preserved. One or more of them may be modified carpals, but they are indistinguishable from phalanges. The broadest phalanx measures 29 mm. Its shaft is marked by a prominent pit which leads into a medullary cavity similar to that of the femur.

Breadth of the smallest carpal	0.028 m.
Breadth of the largest carpal	0.050 m.
Length of the largest carpal	0.041 m.

The first phalanx has a medullary cavity filled with calcite. From this cavity canals lead to the upper and lower surfaces, as in the humerus. The ends exhibit surfaces which were apparently covered with a richly vascular cartilage. It is quite evident that all of the carpal elements were embedded in a mass of cartilage and that possibly this cartilage included the ends of the proximal phalanges.

The phalanges of the second, third, fourth and fifth digits consist of cylindrical elements, with thickened ends.

Measurements of the Metacarpals and Phalanges.

Length of metacarpal I	0.033 m.
Length of phalanx I of digit I	0.032 m.
Length of metacarpal I	0.035 m.
Length of smallest phalanx in the first digit	0.020 m.

The *pelvic girdle* is represented by an incomplete pubis (plate IV, fig. 4) and an ilium belonging to the right side. The ilium is a slender, smooth, somewhat crushed bone, with expanded distal articular surfaces. The median portion of the ilium is somewhat constricted. At the proximal ends it is obliquely expanded for articulation with the sacral rib. The distal end is rounded, and is marked by numerous small vascular pits and canals. The ilium, like the humerus, is marked by the teeth of some Cretaceous fish.

Measurements of the Ilium.

Length	0.148 m.
Width at proximal end	0.018 m.
Width at distal end	0.054 m.
Length of the sacral rib articular fossa	0.043 m.
Width of the sacral rib articular fossa	0.028 m.

The portion of the pubis (plate IV, fig. 4) consists of the articular portion. It is marked, as are the other elements of the skeleton, by fine vascular pits and lines. The diameter of the articular end is 0.037 m.

Hind paddle. The left femur of the hind limb is preserved. It is distinguished from the humerus by its slender, nearly straight form (plate IV, fig. 1) and its almost circular cross-section at the proximal end. There are no sharply defined articular facettes. On the superior surface there is a roughened process for strong muscular attachment. Its position is such that this process can be regarded in a certain sense as a trochanter.

On the radial surface of the femur there is a distinct rounded foramen, similar to those described by the writers elsewhere. Since the bone is broken at the plane of this foramen, it shows that the foramen is the opening of an elongate rounded canal, which in turn leads into a large medullary cavity which sends spicular spaces into the surrounding bone. (Plate III, fig. 3.) This condition has been commented on several times, but no explanation has been offered to explain it. The structure has all of the appearance of the so-called "periosteal buds" so commonly figured in textbooks of microscopic anatomy.

Measurements of the Femur.

Length	0.175 m.
Diameter of the lateral foramen	0.006 m.
Diameter of the medullary cavity	0.015 m.
Length of the canal	0.020 m.
Length of the medullary cavity	0.025 m.
Length of one of the smaller canals	0.001 m.

In view of the possibility of identity, or at least a close relationship, between *Ogmodirus* and *Embaphias circulosus* Cope, we give herewith figures of the best of the type specimen of this genus and species (plate V) as it is now preserved in the Academy of Natural Sciences of Philadelphia. The type, collected by Mr. F. H. Charles from the Great Bend of the Missouri river, South Dakota, in 1893, consists of two dorsal and one cervical vertebra. The specimens present no generic characters and can not be again

recognized until more complete specimens from the same locality and horizon are studied. That they belong to a short-necked plesiosaur is probable, and this may be *Polycotylus* or something allied to it; though if the horizon is the Pierre Cretaceous, as is probable, the generic identity would be more doubtful. The greater concavity of the dorsal centra also indicates a distinct genus.

The cervical is flattened, nearly circular in outline, rather strongly concave; a single large vascular foramen below, but no ridge or fossæ, but very slightly concave from margin to margin. The articular rim encroaches much on the exterior.

The diapophyses stand out moderately; vertically elongate, connected by a narrow surface upward on the arch. The lower extremity of the articular surface, however, reaches pretty well down on the ventrum.

Transverse diameter of the centrum	84 mm.
Vertical diameter of the centrum	78 mm.
Length	45-48 mm.

The better of the two dorsals is deeply cupped, circular in outline, with rather sharp rims, rather deeply concave on the sides and below, and circular in cross-section through the middle; vascular foramen situated high up on sides, above the middle.

Length below	55 mm.
Length above	51 mm.
Transverse diameter	100 mm.
Vertical diameter	92 mm.

DESCRIPTION OF PLATES.

PLATE I.

The cervical vertebræ of *Ogmodirus martinii*, photographed from the ventral surface. $\frac{1}{3}$ natural size.

PLATE II.

The left fore paddle of *Ogmodirus martinii*, photographed from the dorsal surface. The elements are of doubtful association. $\frac{1}{3}$ natural size.

PLATE III.

Fig. 1. The right humerus of *Ogmodirus martinii*, photographed from the dorsal surface and showing at *S* the tooth marks of some predaceous fish. $\frac{1}{2}$ natural size.

Fig. 2. The distal end of the humerus, showing the pits and cones, resembling miniature volcanoes, the results doubtless of the exit of the *Canales ossificantes perforantes* carrying osteoblasts. $\frac{1}{2}$ natural size.

Fig. 3. A photograph of a broken section through the femur. This section shows, on the right, the canal leading into the calcite-filled cavity. These features are apparently growth characters.

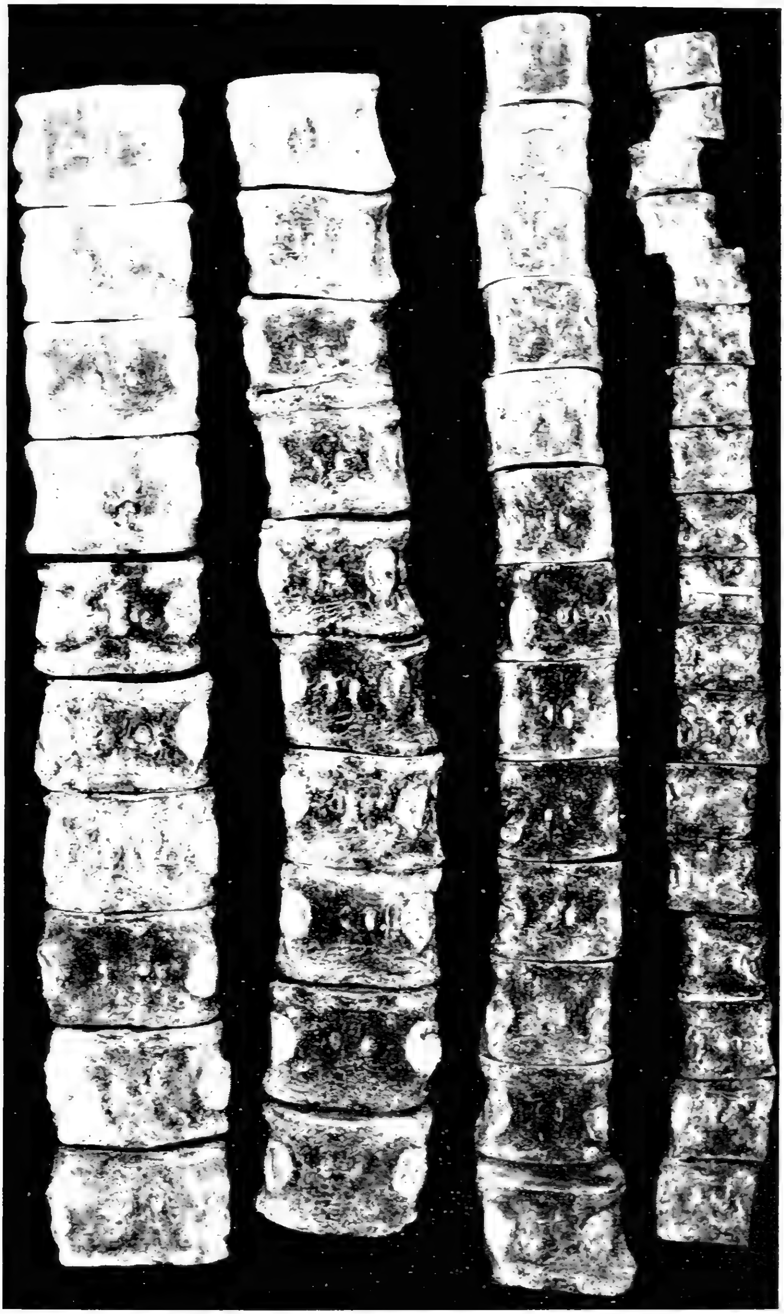
Fig. 4. A photograph of the proximal end of the humerus to show at *A* the pits and cones.

PLATE IV.

FIG. 1. The left femur of *Ogmodirus martinii*. $\frac{1}{3}$ natural size.
FIG. 2. Neural spines.
FIG. 3. The right ilium.
FIG. 4. A portion of a pubis.
FIG. 5. Two views of a cervical vertebra.

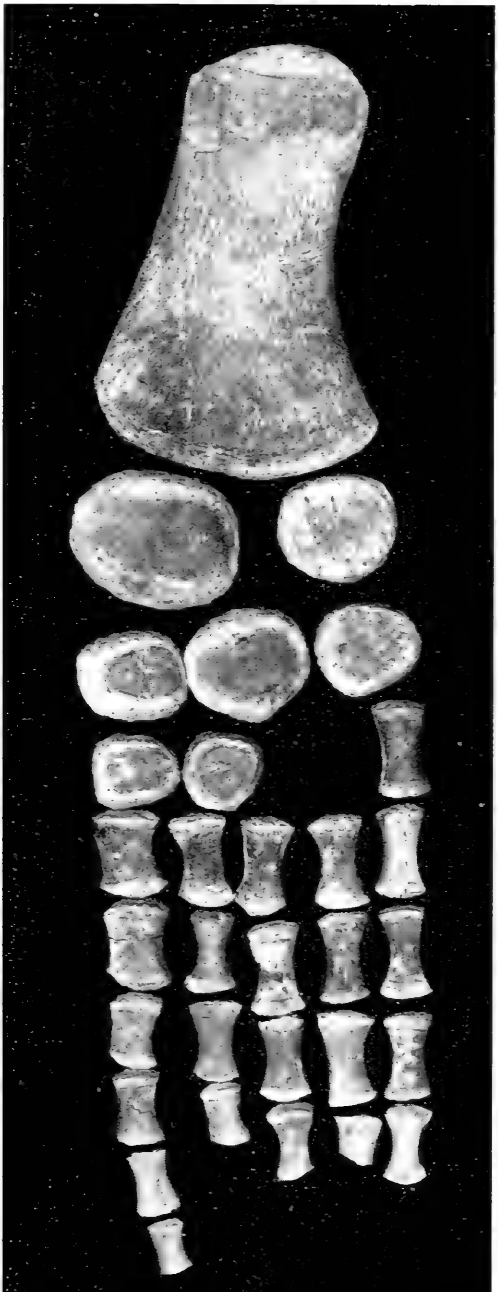
PLATE V.

The vertebræ of the type of *Embaphias circulosus* Cope. Specimens in the Academy of Natural Sciences of Philadelphia: 1 and 2, lateral and end views of vertebra; 3 and 4, lateral and end views of other vertebra.



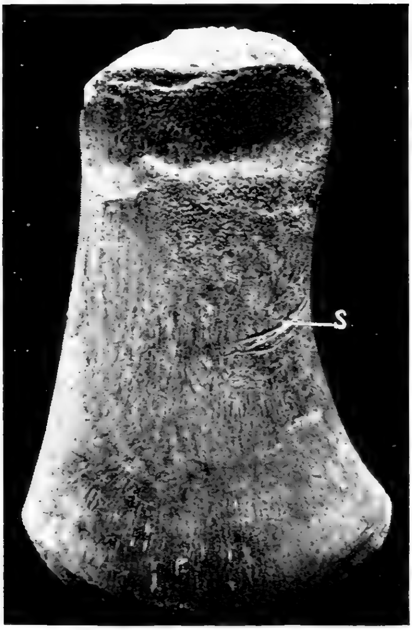
OGMODIRUS MARTINII.
Williston and Moodie.

PLATE II.



OGMODIRUS MARTINII.
Williston and Moodie.

PLATE III.



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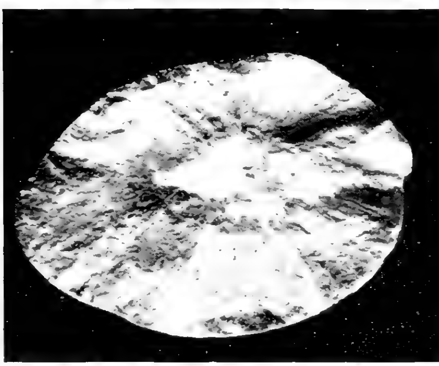

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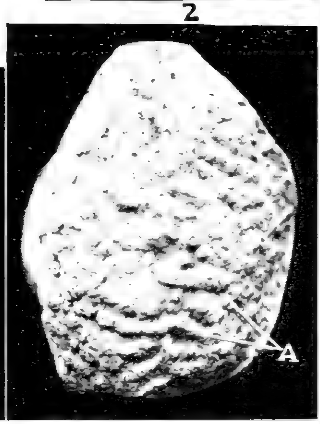

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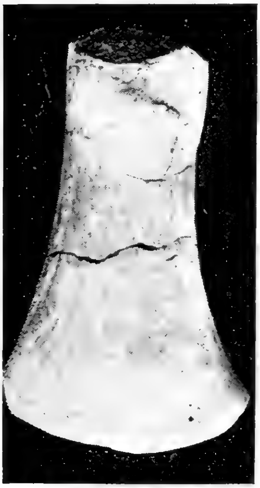
Ogmodirus Martinii.
Williston and Moodie.

PLATE IV.



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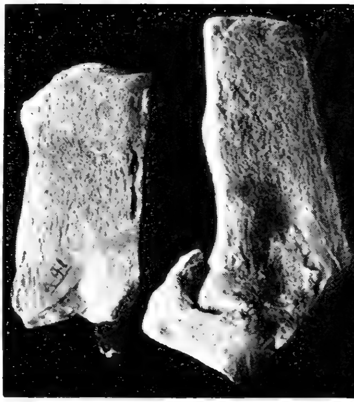

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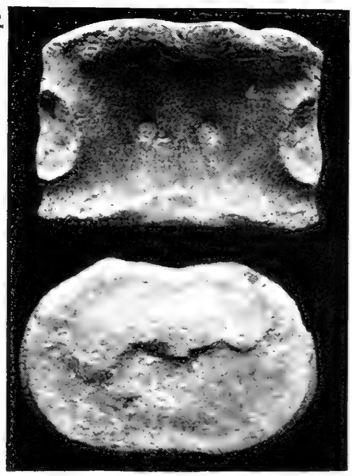

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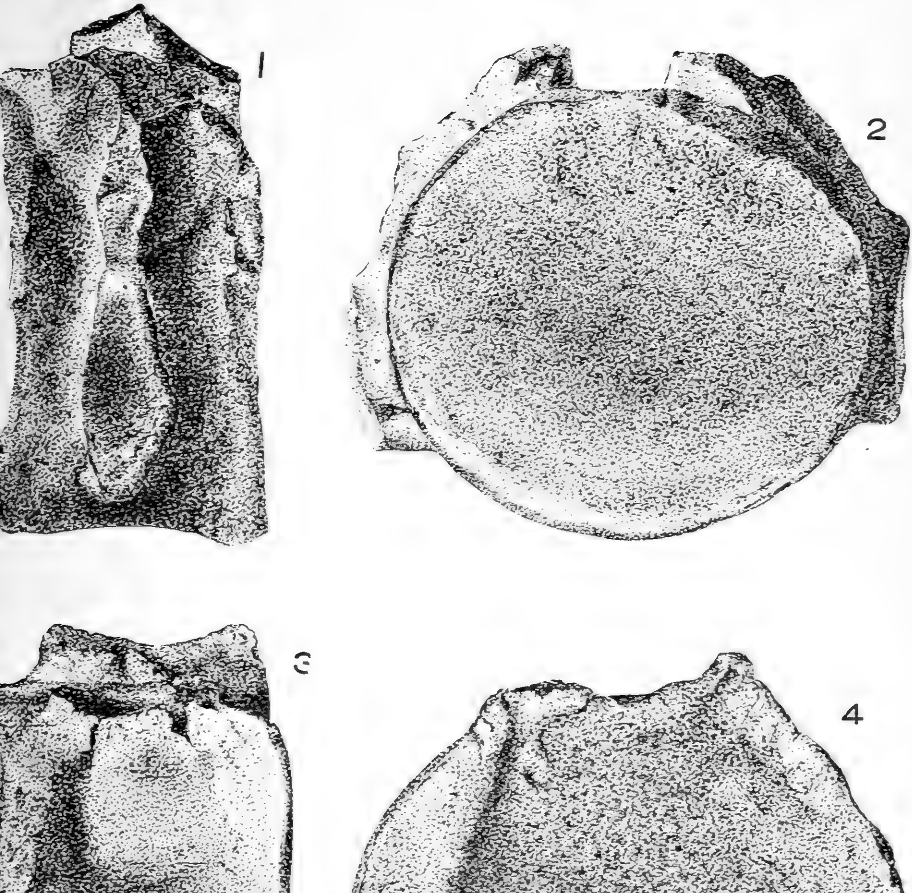
OGMODIRUS MARTINII.
Williston and Moodie.

PLATE V.



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An Anatomical Study of *Cycloloma atriplicifolium.*

BY DUDLEY J. PRATT.

A thesis submitted to the Department of Botany and the Faculty of the Graduate School in partial fulfillment of the requirements for the master's degree.

INTRODUCTION.

CYCLOLOMA ATRIPLICIFOLIUM is a coarse annual native to the central part of North America. The typical form of this hardy xerophyte is found in the Niobrara sand hills, according to the Phytogeography of Nebraska ('09). There the small, slender, moderately branched form found in other localities becomes a great bushlike type (5 dm. to 2 meters in diameter and 1 meter high), called the giant tumbleweed, which is well adapted to the tumbling habit because of its subglobose, compact top and innumerable seeds. The spreading tops and close aggregations of these tumbleweeds, sometimes several hectares in extent, crowd out other plant growth from the sandy plains or summits of the sand hills. On tilled soil, however, the smaller form of this weed is not hard to combat. The Iowa Geological Survey ('13) states the weed is easily exterminated in that state by cultivation.

There has been no anatomical work done on *Cycloloma,* recorded in the literature accessible to the writer, but there has been some ecological study of the genus, and of the species *atriplicifolium.* Bentham and Hooker ('80), and Engler and Prantl ('89), classify *Cycloloma* under the Chenopodieæ, and describe the genus. Solereder ('08) discusses the anatomical features of the Chenopodieæ, but does not include *Cycloloma* among the genera mentioned. Descriptions of both the genus and species are given by Britton and Brown ('13), Coulter ('09), and Gray ('08).

The plant studied was collected by Professor W. C. Stevens, of the University of Kansas, September 5, 1915, on dry upland

four miles southeast of Pratt, Kan. When gathered it was placed in a two per cent formalin solution. The specimen is ordinary in size, and is fresher than those commonly found in the early fall, due, no doubt, to the unusually frequent summer rains.

METHOD OF PROCEDURE.

The methods of anatomical study employed by Stevens ('11) were followed. Microchemical tests were made on sections cut free-hand with the razor. Microtome sections of all sizes of stem and root were made, and sections were made of five regions of stem and root imbedded in both paraffin and celloidin. Region I (fig. 29, *m''*) of the stem was cut within 5 mm. of a young branchlet tip; region II (fig. 29, *o''*) within 1 to 3 cm. of a young branchlet tip; region III (fig. 29, *h''*) from a branchlet of medium size; region IV (fig. 29, *r''*) from the base of a main branch; and region V (fig. 29, *s''*) from the main axis, 7 cm. above the root, where the diameter is approximately 1.5 cm. The sections of the five regions of root correspond in size to the five regions of stem. The general drawings mapping out tissue regions were made from material not imbedded, but the detail drawings were made for the most part from material imbedded in paraffin, but in a few instances in celloidin. All drawings were made with the use of the projectoscope.

THE STEM.

The main axis of the stem in my specimen is 15 cm. long; it varies in diameter from 2 cm. close to the root to 1 cm. where the last branches go off. From this main axis arise uniformly twelve erect branches, which are not straight but irregularly zigzag, and which are diffusely branched to fill out the globose contour of the plant. The bases of the two uppermost main branches unite to form the tip of the main axis of the stem. The branching habit of a main branchlet is shown in fig. 1. The stem has a glabrate surface, and a light green color with a purple tinge; but parts of the main axis and the large branches are colored a light brown. Due to a well-developed vascular system and collenchyma tissue of the ribs, even the branchlets are very resistant to breaking.

The zones of tissue for the five regions of stem are mapped out in figs. 2, 3, 4, 5 and 6; the detail of the tissue for the first four upper regions of stem is found in figs. 7, 8, 9, 10, and 11. The tissues of the five regions of stem, from the epidermis to the pith, inclusive, are described in the following paragraphs. Discussions

of the primary vascular bundles and of the woody cylinder of the stem follow.

The epidermis consists of one layer of cellulose-walled cells, the lumina of which appear rectangular or circular in cross section. The cell walls show more thickening down through the regions II and III (figs. 8, *a*, and 9, *a*); and the lumina of the cells in region IV (fig. 10, *a*) have become very small because of this thickening. The external wall, which is thicker than the other walls, does not have a cutinized layer in young and medium-sized stems, but develops a cuticle, which, although a very thin film in region I (fig. 7), is more prominent in regions II and III (figs. 8 and 9). The greatest thickness of the cuticle is only .002 mm., attained in region III (fig. 9). The cuticle stains a bright reddish-orange color in chloroiodide of zinc, and bright red in Sudan III and alcannin.

The epidermal cells of the ribs of the stem are elongated longitudinally (figs. 12 and 13) approximately four times their tangential dimensions (fig. 9, *a*), and show a slightly greater dimension tangentially than radially (fig. 9, *a*). The epidermal cells other than those on the ribs of the stem are slightly elongated longitudinally or have relatively equal longitudinal (figs. 14 and 15) and tangential (fig. 9, *a*) dimensions, and have greater tangential than radial dimensions (fig. 9, *a*). The inner tangential wall of the epidermal cells joins up in a somewhat irregular line with the primary cortex cells (fig. 10, *a*). In surface view *Salsoli kali* also has lengthened epidermal cells of the ribs and isodiametric epidermal cells between the ribs, according to Solereder ('08).

The epidermis of very young stems is thick.y covered with clothing and glandular hairs (figs. 16 and 17). As would be expected, the hairs are not so numerous in region II as in region I; still fewer hairs are found on region III, and usually only basal portions of hairs remain in region IV. The hairs of the stem are discussed later with the hairs of the leaf.

The stomata of the epidermis of the stem are like those described for the leaf in this article, and are almost as numerous, there being 117 per sq. mm. (Figs. 12 and 14.)

Subepidermal groups of collenchyma (fig. 9, *b*) projecting as ribs; groups of parenchyma (fig. 9, *c*) intervening between the ribs; also parenchyma (fig. 9, *i*) between the collenchyma groups and the starch sheath; and the starch sheath (fig. 9, *d*), make up the primary cortex.

The collenchyma cells in the outer part of the rib, then the cells situated farther in, are differentiated from the ground meristem by thickening of the cellulose walls as shown in regions I and II (figs. 7, *b*, and 8, *b*). The collenchyma, which is the sole strengthening tissue in region I, contains chloroplasts. In cross section the cells are usually as large as the epidermal cells or larger. A longitudinal view of the collenchyma cells of region III is shown in fig. 18. In region IV (fig. 10, *b*) we see the collenchyma has reached a greater development than higher up, and the lumina of the cells are smaller because of the thickening of the cell walls.

In most ages of stem seven groups of collenchyma, corresponding to the seven prominent ribs, are present. There are three main ribs in region I (fig. 2), giving this region of the stem a triangular shape. Ten ribs are present in region V (fig. 6).

The chlorophyllous tissue between the ribs is made up of ordinary parenchyma cells, the walls of which are thickly lined with chloroplasts (fig. 7, *c*). There are no intercellular spaces among these cells in region I (fig. 7, *c*); a few occur in the outer part of the chlorophyllous tissue of region II (fig. 8, *c*); and quite a number are present in region III (fig. 9, *c*).

On certain sides of the stem the cell walls of one to six rows of parenchyma cells, just exterior to the starch sheath, in region IV, (fig. 10, *o*) suberize their cell walls. These cells resemble the cells of the starch sheath in shape and size, and have thicker walls than the other parenchyma cells of the primary cortex. A phellogen layer arises in the parenchyma of the primary cortex on various sides of the stem in region V and below and forms cork (figs. 6, *b′*, and 19, *b′*) and lenticels (figs. 6, *a′*, and 20, *f′*). The epidermis and cells of the primary cortex exterior to the newly formed cork are sloughed off. According to Georghieff (*fide* Solereder, '08), the cork arises in the primary cortex in *Kochia* also, an allied genus. Solereder ('08) states that cork may be formed externally or internally in the Chenopodieæ; internally it is generally formed in the pericycle.

The starch sheath is well defined in all regions of stem by the shape and size of its cells, most of which have a long tangential dimension (fig. 9, *d*) and are lengthened longitudinally (fig. 21, *d*). The radial and the outer tangential walls of the starch sheath cells in portions of region V have become suberized.

The ground tissue of the pericycle has just been formed from the ground meristem in region I (fig. 7, *e* and *f*). In this region of stem two areas of the pericycle are distinguishable by the size of

their cells. The outer area of the pericycle is made up of small cells, which contain chloroplasts in very young stems (fig. 7, *e*), and the inner area of the pericycle is made up of much larger cells (fig. 7, *f*). There are three areas of pericycle in region II (fig. 8, *e′*, *e″* and *f*), and all the pericycle cells are larger in region II than in region I (fig. 7). The areas of pericycle *e′* and *e″* in fig. 8 correspond to the area of pericycle *e* in fig. 7. The cells in the outermost area of the pericycle (fig. 8, *e′*) have cellulose walls. In the areas of pericycle *e″* and *f* of fig. 8 the cell walls are lignified.

There is also an outer area of unlignified pericycle in regions III and IV (figs. 9, *e′*, and 10, *e′*). These cells are shown in longitudinal section of region III in fig. 21. The outer longitudinal strip of these cells, two cells deep radially, includes bast fibers. As seen in a cross section of region IV (fig. 10, *f′*) the bast fibers are arranged single or in short chains. This arrangement is found in nearly all the Chenopodieæ, according to Solereder ('08), who states, "it rarely consists of a closed sclerenchymatous ring, and is mostly composed of isolated groups of sclerenchymatous fibers." The occurrence of a sclerenchymatous pericycle is held to be an ordinal character in the Chenopodieæ by Georghieff (*fide* Solereder ('08).

A few bast fibers, irregularly arranged, also occur in three tangential rows of pericycle cells, just interior to the outermost row, in cross sections of region V (fig. 22, *f′*) and below. The bast fibers are approximately twice as broad as the wood fibers (figs. 23 and 24). The fibers stain a reddish-brown or a brilliant yellow in chloroiodide of zinc.

The lignification of cell walls in the areas of pericycle *e″* and *f* of fig. 9 in region III is more complete than in the corresponding areas of pericycle in region II (fig. 8). The cells of the area of pericycle *e″* of region III are shown in longitudinal section in fig. 25. In certain cross sections of region IV the two outer rows of cells of the central area of pericycle (fig. 11, *e″*) have thick lignified walls, and the outer cells in this area of pericycle have cellulose walls. The cell walls in the innermost area of pericycle are cellulose (fig. 11, *f*).

Generally all the cell walls in pericycle areas *e″* and *f* in fig. 11 of region IV are cellulose, or are very slightly lignified. The cell walls of the corresponding areas of pericycle in all regions of the stem below region IV are cellulose, or are very slightly lignified. (See the areas of pericycle of fig. 26, *e″* and *f*, in region V.) The

cells included in these areas of pericycle resemble pith cells, in shape and nature of cell walls.

The cell walls of the primary medullary rays are cellulose upward from a little above region II, as shown in fig. 7, *g*, of region I, and remain cellulose in certain sections of region IV (fig. 11, *g*). The cell walls of all but a few of the innermost cells of the primary medullary rays are lignified in regions II and III (figs. 8, *g*, and 9, *g*), and in some sections of region IV. The primary medullary ray cells, the walls of which are delicately pitted, are shown in longitudinal sections of region III in fig. 27.

The lignification of the cell walls in the pericycle areas *e''* and *f* (fig. 9) and the primary medullary rays in regions of stem from region IV up to a little above region II would seem to give strength and elasticity to these regions of stem. Probably the anomalous structure which forms a greater part of the woody cylinder of the stem in region IV and below (as described later) strengthens these regions of the stem sufficiently to make unnecessary the lignification of the cell walls of the pericycle areas *e''* and *f* and the primary medullary rays oftentimes in sections of region IV, and in all sections of regions below.

The pith cells are shown in longitudinal view in fig. 28. The cells of the pith do not break down to form hollow spaces, but persist in older sections of the stem. Generally the cell walls of the pith stain a deep purple color in chloroiodide of zinc, but also stain a delicate red with phloroglucin.

THE PRIMARY VASCULAR BUNDLES.

The primary vascular bundles are mapped out for region I in fig. 2; region II, fig. 3; region III, fig. 4; and region IV, fig. 5. Usually one or two of the primary vascular bundles of larger size are situated opposite each of the main ribs of the stem in regions I, II, and III. The course of the primary vascular bundles in the stem is mapped out in fig. 29, *j*. In regions above region IV the leaves remain on the stem, and the leaf traces traverse a portion of the anomalous structure (fig. 29, *t''*). The course of the leaf-trace bundles out of the stem up through the petiole into the leaf is discussed later. The leaf traces are broken apart in region V and below (fig. 29, *u''*) by further development of the anomalous structure.

The primary vascular bundles are differentiated into the phloëm and xylem elements in region I (fig. 30, *h'* and *j'*). In cross section some of the cells of the phloëm elements have walls unusually

thick for this region. This feature is discussed later. The central strip of procambium and the young water tubes of the primary xylem can be clearly discerned (fig. 29, *i'* and *a'''*). Immediately down the stem from region I the leaf-trace bundles appear in the pericycle (fig. 31, *k*), where they are crossing out into the leaf, and the cambial layer of the primary vascular bundles is discernible (fig. 31, *n'*). Some secondary phloëm and xylem have been formed by the cambial layer in region II (fig. 32, *m'* and *o'*).

In longitudinal sections of region III the sieve tubes, the companion cells and the phloëm parenchyma cells are discernible, as shown in figs. 33 and 34, *b'''* and *c'''*. In cross section the sieve plates are difficult to distinguish, their pits being very small (fig. 34, *d'''* and *f'''*). Certain sieve tubes have thickened their cell walls (fig. 34, *d'''*) and others have not (fig. 34, *f'''*). The cambium is active yet in a few of the bundles. Spiral and annular tracheæ of primary xylem are shown in figs. 36, 37 and 38. The parenchyma of primary xylem does not lignify.

In the secondary xylem of the primary vascular bundles the tracheæ have circular lumina, and are prominent. The tracheæ are pitted, having slightly elongated, bordered pits (fig. 39), or are of reticulate type (fig. 40). Solereder ('08) states, the tracheæ in the Chenopodieæ usually have simple pits, but mentions the genus *Axyris* as an exception. Georghieff (*fide* Solereder, '08) records scarlariform perforations with oblique, almost longitudinal, bars in *Axyris amarantoides*. At intervals portions of the cross walls of the elements of the tracheæ remain (fig. 39). The wood parenchyma cells of the secondary xylem of the primary vascular bundles are ordinary in size and shape, and have few and only inconspicuous pits (fig. 41). Wood fibers were not found to occur in the xylem of the primary vascular bundles. The fiber tracheids, which are rather few, vary in size and shape, and have bordered pits (fig. 42).

In the primary vascular bundles of region IV (fig. 43, *m'* and *o'*) more secondary phloëm and xylem are present than in the corresponding bundles of region III. The wood parenchyma of the secondary xylem of these bundles in this region of stem is well lignified.

A leaf-trace bundle with an active cambial layer is shown in fig. 31, *k*, and an older leaf-trace bundle in region IV is shown in fig. 44. The leaf-trace bundles do not grow to be very large. The cambial layer in most of the leaf-trace bundles of region III has ceased its activity. Solereder makes the following statement con-

cerning the development of the leaf-trace bundles in the Chenopodieæ: "The leaf-trace bundles sometimes possess considerable growth in thickness, and thus delay the appearance of the anomalous growth (*Camphorosma* and *Echinopsilon,* as also *Blitum virgatum, Chenopodium murale* and *C. hybridum,* according to De Bary, *Kochia prostrata* according to Georghieff.)"

As seen in some cross sections of region IV, and regions farther down the stem, the primary vascular bundles are very irregularly arranged, are more numerous than in regions higher up, and have the appearance of being imbedded in the pith. (See figs. 5, *j*, and 6, *j*.) This appearance is due to the fact that the cells in the areas of primary pericycle *e''* and *g* of fig. 26 and the cells of the primary medulary rays (fig. 44, *g*) in these regions of stem resemble pith cells in shape, and appearance of cell walls, which have remained cellulose or are very slightly lignified.

A few cells of the area of pericycle, *e''*, which have cellulose walls, are shown in longitudinal section of region IV in fig. 46. In regions of stem from region IV on down, parts of the anomalous xylem, which is first formed exterior to the primary vascular bundles by anomalous growth, resemble pith. This is shown for region V in fig. 26. A discussion of the origin and nature of the anomalous tissue appears later in this article.

The following statement quoted from Solereder ('08) throws light upon the pith-like appearance of the primary pericycle and primary medullary rays in most sections of region IV and all sections of regions below: "In the Nyctagineæ, Amarantaceæ and Chenopodiaceæ the ground tissue situated between the primary vascular bundles and the tissue formed at the commencement of the activity of the secondary meristem is occasionally differentiated like a pith, and in such cases the primary vascular bundles appear as apparent medullary bundles." Solereder also states that the vascular bundles, which he terms medullary bundles, appear in certain members of the Chenopodieæ, and adds that their development in this order shows that these bundles are rarely true medullary bundles, but are the normal leaf-trace bundles. According to Georghieff (*fide* Solereder), true medullary bundles occur in *Acroglochin persicarioides* Moq.

Evidently the primary vascular bundles of *Cycloloma atriplicifolium* have the same appearance in region IV and regions on down the stem as have the bundles which Solereder terms apparent medullary vascular bundles.

THE WOODY CYLINDER.

In region II there is a beginning of the formation of a woody cylinder, consisting of xylem groups of primary vascular bundles (fig. 3, *j*), and lignified pericycle (fig. 3, *e''* and *f*) and primary medullary rays (fig. 3, *g*), and holding imbedded the strands of phloëm belonging to the vascular bundles (fig. 3, *j*). The woody cylinder of region II is mapped out in fig. 3, and the detail of the tissue of the woody cylinder in a portion of a cross section of region II is shown in fig. 8. The woody cylinder in region III, mapped out in fig. 4, is larger than in region II, due to the larger size of the cells of the areas, *e''* and *f*, of the primary pericycle (fig. 9) and primary medullary rays (fig. 9, *g*) included, and to the addition of anomalous xylem (fig. 4, *m*), formed by anomalous growth.

The anomalous growth consists in the formation of one or several broad zones of xylem around the stem, and a narrow, broken zone of tissue (made up of phloëm groups, secondary medullary rays, and from one to several rows of pericycle cells exterior to the phloëm groups and secondary medullary rays), having thin cell walls and located just exterior to each xylem zone, both kinds of zones being formed by broken rings of arcs of secondary meristem, which arises successively around the stem in the pericycle. The arcs in each successive ring of arcs of secondary meristem are active for a time, but cease their activity before the next younger ring of arcs arises.

For convenience in presentation of the anomalous structure, frequently in this article the broad xylem zones are designated as xylem zones, and the narrow, broken zones having thin cell walls, as phloëm zones.

The number of cells in the outer area of pericycle is considerably greater in region III (figs. 4, *e'*, and 9, *e'*) than in region II (figs. 3 and 8). On various sides of the stem, arcs of the inner rows of the cells in this area of pericycle have just produced a secondary meristem in region III (fig. 47, *n*), and other secondary arcs, having arisen earlier on other sides of the stem, are in different stages of progress (figs. 48, *n*, and 49, *n*). Anomalous xylem has been formed on some sides of the stem in region III by the secondary arcs of meristem, as shown in figs. 4, *m*, and 29, *p''*, and 48, *m*. On some sides of the stem the secondary arcs have not yet arisen, as shown in fig. 9, *e'*.

In regions of stem just below region III, the arcs latest to be differentiated in the first ring of secondary arcs have arisen; and

a xylem zone around the stem (figs. 29, *q''*, and 50, *p*) and a phloëm zone located just exterior to the xylem zone (figs. 29, *q''*, and 50, *q*) have been formed in regions of stem a little farther down. The outer and inner borders of the two zones are very irregular in boundary (figs. 29, *q*, and 50, *p* and *q*), due to the varied activity of the first ring of secondary meristematic arcs, which is described in the following paragraph.

As seen in cross section, the formation of the xylem zone, and the narrow zone just exterior to the xylem zone, is as follows: Various arcs of the secondary meristem form radial strips of xylem on their inner side, and small, isolated groups of phloëm on their outer side (fig. 51, *n''*); some secondary arcs form radially longer strips of xylem on their inner side and do not form phloëm on their outer side (fig. 51, *o''*); and other secondary arcs form radial strips of xylem, and secondary medullary ray tissue between the phloëm groups (fig. 51, *p''*). What else can this area of tissue (figs. 50, *r*, and 51, *r*) located between the groups of secondary phloëm be called other than a secondary medullary ray? The xylem-phloëm zone is mapped out in fig. 50, *p* and *q*.

The outer two rows of cells of the phloëm zone, shown in figs. 50, *t*, and 51, *t*, are pericycle cells; the rest of the narrow zone is made up of the phloëm groups (figs. 50, *s*, and 51, *s*) and the secondary medullary rays (figs. 50, *r*, and 51, *r*); and the phloëm zone is interrupted by certain radial, anastomosing strips of xylem (figs. 50, *u*, and 51, *u*).

As seen in cross section, the newly formed anomalous xylem zone (figs. 50, *p*, and 51, *p*) coalesces with the outer part of the lignified primary pericycle (figs. 50, *e''* and 51, *e''*). The anomalous xylem stains a light yellow color in chloroiodide of zinc (figs. 50, *p*, and 51, *p*); the part of the woody cylinder formed from lignified pericycle and primary medullary rays, a yellowish-brown (figs. 50, *e''*, *f*, and *g*, and 51, *e''*, *f*, and *g*). The anomalous xylem and the primary tissue included in the woody cylinder stain uniformly with phloroglucin.

In region IV (figs. 5, and 29, *r''*; and 10) more xylem zones, and the phloëm zones alternating with the xylem zones in a radial direction, have been formed by the successive rings of arcs of secondary meristem, arising in the pericycle. The arcs in the rings of secondary meristematic arcs, arising later than the first ring of secondary arcs, do not have their origin directly exterior to the phloëm groups previously formed by the next older ring of secondary arcs, as illustrated in fig. 48, *n*, where a secondary arc

has just arisen. A similar arc, forming the fourth ring of xylem in region IV, is shown in fig. 52, *n*. The arcs, in a ring of secondary arcs of one region of stem, anastomose both tangentially and radially with the arcs, in the corresponding ring of secondary arcs, in the region of stem below (figs. 5, *n*, and 29, *n*).

The number of xylem-phloëm zones on the various sides of the stem may differ, ranging from two to four in region IV (fig. 5); from five to eight in region V (fig. 6); and from eight to twelve in the part of the main axis having the greatest diameter.

The xylem groups of the primary vascular bundles are not included in the woody cylinder in region IV; for only the outer part of the primary pericycle, on various sides of this region of stem, lignifies completely enough to be included as a part of the woody cylinder (figs. 5, e'', and 11, e''), and the rest of the woody cylinder in region IV is anomalous tissue, composed of the xylem zones holding imbedded the phloëm zones, as shown in figs. 5, and 29, r''. On other sides of the stem, in region IV, all the cells of the primary pericycle (fig. 5, e', e'', and *f*) and primary medullary rays (fig. 5, *g*) have cellulose walls, and are not included in the woody cylinder. In all regions of stem below region IV, none of the cell walls of the primary pericycle (fig. 25, e', e'' and *f*) and primary medullary rays (fig. 44, *g*) have lignified deeply enough to be included in the woody cylinder, and the woody cylinder in these regions of stem has been formed by anomalous growth only. (See figs. 6, and 29, s''.)

The relative radial breadth of the xylem-phloëm zones is shown in cross section in figs. 5 and 6. The anomalous zones are complete rings around the stem, or as segments of rings have an irregularly concentric arrangement in cross section, and undulate slightly in a radial direction in their course around the stem (figs. 5 and 6). The xylem zones and the phloëm zones anastomose both tangentially and radially (figs. 5, *u*; 6, *u*; and 29, *u*).

The xylem zones are generally made up of the tracheæ, a few lignified parenchyma cells bordering the tracheæ, and the numerous wood fibers (fig. 51, *p*). The wood fibers are shown in longitudinal view in fig. 24. In some sections of region V and below, the tissue lying on the inner side of some of the xylem zones is made up entirely of wood fibers (fig. 53, p''); and the remainder of the xylem in each of these xylem zones (about 80 per cent of the entire zone) is composed of wood parenchyma and tracheæ (fig. 52, q'').

One or several inner rows of cells, or almost all the inner half, of the innermost anomalous xylem zone, on certain sides of stem in some cross sections of region V (fig. 26, *c'*), and in all cross sections of regions of stem below, is made up of thin-walled cells, which resemble pith cells in cross section in shape and relative size and have cellulose or slightly lignified walls (figs. 54 and 55). The rest of this zone is of the usual xylem structure (fig. 25, *d'*).

Spiral tracheæ are not present in the xylem of anomalous growth. The tracheæ are arranged in radial rows associated with other tracheæ scattered through each xylem zone (figs. 26 and 51), or have a very irregular arrangement (figs. 50 and 53). The lumina of the tracheæ are usually circular in shape, but some are oval. The lumina of the tracheæ range from .010 to .080 mm. in diameter, being relatively quite large, when compared with the lumina of the tracheæ in other members of the Chenopodieæ. Solereder ('08) states the usual diameter is .015 to .045 mm. in the Chenopodieæ.

The lumina of the tracheæ are usually larger in the xylem zones (fig. 53, *p*) external to the innermost xylem zone (fig. 51, *p*), but the number of tracheæ and the sizes of the lumina of the tracheæ are the same for relative areas of each of the xylem zones exterior to the innermost xylem zone.

In cross sections the wood fibers appear irregular in shape and arrangement (fig. 53, *o''*), or may be rectangular or almost square and arranged regularly in radial rows (fig. 57).

The innermost anomalous phloëm zone has been described above. The other phloëm zones resemble the innermost phloëm zone, but are somewhat broader, being composed of larger groups of phloëm (fig. 57, *s*), larger regions of secondary medullary ray tissue (fig. 57, *r*), and two or more rows of pericycle cells located exterior to the phloëm groups and secondary medullary rays (fig. 57, *t*). The anomalous phloëm, although the cells are larger, resembles the phloëm of the primary vascular bundles (fig. 57, *s*). The cell walls of most of the secondary medullary rays lignify to some extent, but are thin (fig. 57, *t*). A few cells of a secondary medullary ray, the walls of which are cellulose, are shown in longitudinal section in fig. 59. The pericycle cells, in each phloëm zone, located exterior to the phloëm groups and secondary medullary rays (fig. 58, *t*) are similar to the cells of the secondary medullary rays in size, shape and nature of cell walls. A longitudinal view of these pericycle cells is shown in fig. 60.

As seen in cross section (figs. 5, *q*, and 6, *q*), the three inner phloëm zones are interrupted by numerous radial anastomosing strips of xylem (figs. 5, *u*, and 6, *u*). The other phloëm zones are traversed by a much lesser number of these (fig. 6). The radial strips of xylem are usually made up of wood fibers, as shown in fig. 10, *u*, although some contain tracheæ, as shown in fig. 56, *u*. The peculiar location of these radial anastomosing strips of xylem is due to the varied activity and anastomosis of the arcs of secondary meristem by which the radial anastomosing strips of xylem were formed. The anastomosis of the arcs of secondary meristem is described above. The phloëm zones in region V and below are joined up in cross section by radial anastomosing strips of tissue having cells which resemble the secondary medullary ray cells (figs. 6, *g′*, and 58, *g′*).

As seen in cross section, in the anomalous zones there are radial rows of cells having a radial dimension from two to four times as great as their tangential dimension (fig. 58, *g‴*). These radial rows of cells are narrow, being only one to four cells broad tangentially. None of these radial rows of cells in the sections examined extend entirely from the outer to the inner zone of anomalous growth, but generally traverse only a few zones. In the phloëm zones these cells are pericycle cells (fig. 58, *h‴*) and secondary medullary ray cells (fig. 58, *i‴*). In the xylem zones these cells resemble wood parenchyma in size and proportion, and have thick, slightly lignified walls (fig. 57, *j‴*).

As far as the writer has been able to ascertain, no use made of the anomalous structure by the plant has been mentioned in the literature available.

I am of the opinion that the anomalous xylem is an ample strengthening tissue, and serves principally for water storage, not so much for conduction. Probably the xylem of the primary vascular bundles conducts sufficiently for the transpiration of the leaves. The leaf-trace bundles traverse the two innermost anomalous xylem-phloëm zones in region IV (fig. 29, *t″*). Below region IV the leaf-trace bundles are broken apart by further anomalous growth (fig. 29, *u″*), and the leaves do not remain on this region of stem. Evidently from region IV on down the stem all the anomalous xylem zones are available for water storage.

The presence of many phloëm strands in the anomalous structure is quite striking, for it seems there is enough phloëm in the primary vascular bundles to conduct the photosynthetic products of the leaves. But there is much photosynthetic tissue in

the primary cortex in all regions of stem above region V, and on certain sides of the stem in regions below, on sides where the parenchyma has not been destroyed by the formation of cork within, and no doubt so much anomalous phloëm is necessary to store and to transfer the food, made in the photosynthetic tissue of the stem, for use in the rapid formation of the many anomalous xylem-phloëm zones. The photosynthetic products can be transferred readily from the parenchyma of the primary cortex through the starch sheath and pericycle to the anomalous phloëm. The products of photosynthesis may also travel from one anomalous zone to another because of the anastomosis of these phloëm zones (fig. 29, *g′*), and finally to the phloëm of the primary vascular strands, whence presumably it would go to the nutrition of the seeds later in the season.

The anomalous structure found in the Chenopodieæ occurs in all the Chenopodiaceæ having considerable growth in thickness, and is found in the Nyctagineæ and the Amarantaceæ, according to Solereder ('08), in his review of the anatomical features of Chenopodieæ. He quotes from Morot the following statement regarding the course of the development of the anomaly: "Secondary rings or arcs of meristem (the latter anastomosing reticulately) arise in centrifugal succession in the pericycle (internally to the bast fibers, where these are present) and produce secondary vascular bundles as well as conjunctive tissue of varying structure. The xylem portions of these secondary vascular bundles always arise on the inner, the bast portions on the outer side of the secondary meristem."

According to Morot (*fide* Solereder, '08), the appearance of the anomaly in transverse sections of the stem varies greatly between two main types, relatively to the nature of the meristem, and of the tissue intervening laterally between the bundles in each ring of secondary bundles. In the first type the broad, woody rings alternate in the radial direction with rings of tissue having thin cell walls; the woody zones are traversed by medullary rays of varying breadth, the cells of which have thin or lignified cell walls. The rings of tissue with thin cell walls consist of phloëm portions of the vascular bundles associated with variable amounts of a tissue, which Morot terms "parenchymatous conjunctive tissue." In the second type, which occurs more commonly than other types, the vascular bundles are arranged concentrically, spirally, or irregularly, and the bundles are imbedded in tissue, which Morot terms "prosenchymatous interfascicular tissue."

The phloëm groups, which vary in size and are sometimes very small, are associated with lignified or unlignified parenchymatous tissue.

The types of anomalous structure found in the Chenopodiaceæ, Amarantaceæ, Nyctaginaceæ and Tetragonieæ, and in species of *Mesembryanthemum* and *Phytolacca*, are not adaptive anomalies, but merely cases of variation of design; for the abnormal features may be various in the several members of a family, and even in the different species of a single genus, and yet not be connected with the ecological relations of the plants concerned, according to Haberlandt ('14). He makes the following statement concerning the place of origin of the secondary arcs of meristem: "According to Morot, each new arc of cambium arises opposite a phloëm group and extends laterally on each side until it meets an older cambial layer. Herail, on the contrary, maintains that each new cambium begins to develop at one end as a lateral continuation of an antecedent cambial layer; then it extends gradually across the leptome, and sooner or later rejoins an older strip. Leisering believes that both possibilities may be realized."

Anomalies have been found in many lianes as well as in certain small shrubs and herbs, according to Haberlandt ('14), but Hill ('01) has examined an anomaly in *Dalbergia paniculata*, a tree native to south and central India. He states, the anomalous structure is "extremely interesting and equally surprising for a tree attaining the height of sixty feet." From a preliminary examination of the wood, Hill describes the appearance of the anomaly in cross section somewhat as follows: narrow zones of tissue (termed by Hill as "narrow zones of the nature of phloëm") and broad zones of woody tissue alternate in a radial direction. The anomalous zones are traversed by narrow medullary rays. The following statement in regard to the structure of the anomaly in the stem of *Dalbergia paniculata* are quoted from Hill: "By the examination of a transverse section it may at once be seen that the narrow, abnormal zones are of the nature of phloëm, which is accompanied by a certain amount of cambium. This cambium is situated on the side nearer the center of the stem and abuts directly on the xylem elements. . . . The wood is made up of the usual elements; that is to say, vessels, fibers, and parenchyma."

THE ROOT.

The root is a taproot, light brown in color, with approximately the same length and diameter as the main axis of the stem, and having only a few lateral roots attaining much size. Many very small rootlets, with suberized walls for several of their outer layers of cells, are retained throughout the main root. One to several of these arise from each of the numerous grooves in the root. The lateral roots and rootlets extend into the central xylem cylinder or into the first, second or third formed anomalous xylem zone. It has the same habits of growth in thickness as the stem.

The general areas of tissue for regions I, II, III, IV and V are mapped out in figs. 61, 62, 63, 64 and 65. The detail of tissues in regions I, II, III and IV can be found in figs. 66, 67, 68 and 69.

The resemblance in structure of the corresponding tissue of root and stem is so close it is not necessary to give a detailed description of the root here. In very young roots (fig. 66, *b'*) the two or more outer rows of cells become suberized to form cork. Apparently no cork cambium has arisen. Later a few layers of cells, located just interior to these two or more outer rows of primary cortex cells having suberized walls, suberize their cell walls. The cells of the starch sheath can not be clearly discerned, as in the stem, except in portions of certain sections. In figs. 61 and 66 are shown the central xylem cylinder, the phloëm groups of the primary vascular bundle, and the primary medullary rays. The water tubes of the central xylem cylinder are large, and stand out well when stained with phloroglucin (fig. 66, *m''*).

Rings of arcs of secondary meristem arise successively in the pericycle, as in the stem, and form anomalous xylem-phloëm zones. An arc of secondary meristem is shown in fig. 70. In region II (figs. 62 and 67) the anomalous growth has begun, and a second xylem-phloëm zone is starting to form in region III (fig. 63); and the fourth zone, in region IV (fig. 64). From eight to ten xylem-phloëm zones are present in region V (fig. 65); ten to fourteen in the region of the main root having the greatest diameter.

The zones of the anomalous structure are more nearly concentric and broader radially than in the stem. The anomalous zones anastomose both tangentially and radially, but the anastomosis of the first three xylem-phloëm zones is not so frequent as in the corresponding zones of the stem. The three innermost xylem-phloëm zones of the anomalous structure are more nearly concentric than in the stem (fig. 64). The number and arrangement

of tracheæ for unit areas in cross sections is the same as in the xylem zones exterior to the innermost anomalous xylem zone of the stem, but there are relatively more tracheæ having the larger diameter (fig. 65). Commonly the part of the xylem lying on the inner side of the zone is made up entirely of wood fibers (fig. 69, m''), and about 80 per cent of the xylem zone has the usual structure found in the xylem zones of the stem (fig. 69, n''). The walls of the pericycle cells included in each phloëm zone lignify slightly. The cell walls of the secondary medullary rays usually remain cellulose.

Traversing the anomalous zones in cross sections of the root, as in cross sections of the stem, are the radial rows of cells having a radial dimension from two to four times as great as their tangential dimension (figs. 65, g''', and 69, g'''). In the zones of tissue designated as phloëm zones in this article these cells are pericycle cells and secondary medullary ray cells; in the xylem zones these cells resemble wood parenchyma in size and proportion. The walls of many of these cells are lignified, as are the walls of similar cells in the stem; but all these cells in certain sections of the root have cellulose walls, and in many regions of the root are in direct connection with the vascular elements of the very small rootlets, which extend from the exterior grooves into the central vascular cylinder or inner anomalous xylem zones of the main root. The absorbed water is readily transmitted by these cells, included in the radial strips, to all parts of this region of root.

THE LEAF.

The leaves of *Cycloloma atriplicifolium* are alternate and oblong-elliptic, with pointed lobes. Like the stem, the leaves are colored a light green, and are purplish tinged. The leaf is not unusual in structure, and possesses many of the leaf characteristics of the Chenopodieæ mentioned by Solereder ('08). The areas of tissue in a cross section of a typical leaf are mapped out in fig. 71.

The epidermal cells are much more irregular in shape, as seen in cross section, than in the stem (figs. 72, *a*, and 73, *a*). The cells of the upper and lower epidermis are shown in surface view in figs. 74 and 75, and the lengthened cells of the upper epidermis over the main rib are shown in fig. 76. The cell walls of the epidermis are cellulose, except the cuticle, which reaches a thickness of only .001 mm. Solereder ('08) states that in spite of the xerophilous character of many species of Chenopodieæ, the cuticle rarely attains a considerable thickness.

Many clothing hairs (fig. 77) and a few glandular hairs (fig. 78) can be found on the young leaves, but only a few hairs are present on older leaves. Most of the hairs are located at the edge of the leaf, but on young leaves quite a number are scattered over the upper and lower surfaces.

Each clothing hair is seated on a prominent basal cell, above which it consists of a chain of one or more short cells (fig. 77, *a''*), distinguishable by a very thin cuticle from a long terminal portion of one or several cells (fig. 77, *u'*) having thin cellulose walls without cuticle.

The glandular hair has a basal portion made up of a chain of two or more cells with a very thin cuticle (fig. 78, *a''*), and a terminal portion consisting of a row of three or more cells, usually all but the end cell being conspicuous on account of cell contents and a thin cuticle. Cell contents are present in the large spherical or ovoid terminal cell of certain of these hairs (fig. 78, *b'*). The wall of this terminal cell stains blue in chloroiodide of zinc, and does not stain appreciably in Phloroglucin or Sudan III. The contents of the hair cells is discussed in the section on the nature of cell contents.

There are two types of hairs on the stem similar to the hairs on the leaf. A clothing hair of the stem is shown in fig. 16, and a glandular hair is shown in fig. 17.

The stomata are of ordinary type (figs. 74, 75 and 76). Solereder ('08) gives the absence of a definite type of stoma as a noteworthy feature in the leaf of the Chenopodieæ. The cuticle extends over the guard cells (fig. 73, *f''*). The stomata are almost as numerous in the upper epidermis as in the lower epidermis of the leaf, there being 122 stomata per sq. mm. in the upper epidermis, and 128 per sq. mm. in the lower. Usually the long axes of the stomata, as seen in surface view, are placed at an angle with the main rib of the leaf, although many are parallel with the main rib in both young and old leaves. The transverse arrangement of the stomata is not uncommonly shown by narrow leaves in the Chenopodieæ, but also occurs on the stem, according to Solereder ('08).

The mesophyll of the leaf is approximately 65 per cent photosynthetic tissue and 35 per cent water-storage tissue (figs. 71, *c* and *d*; 72, *c* and *d*; and 73, *c* and *d*). Solereder mentions the differentiation of the mesophyll into assimilatory and aqueous tissue as one of the leaf characters of the Chenopodiaceæ correlated with their dry-land habitat.

The water-storage tissue is made up of large cells centrally located and lying next the border parenchyma adjacent to the vascular elements (figs. 72, *d*; 73, *d*; and 79, *d*). The vascular elements of the leaf are imbedded in the mesophyll in closer proximity to the lower than the upper epidermis (figs. 71, *g*; 72, *g*; and 73, *g*). Under the upper epidermis of the leaf is a palisade layer of mesophyll, and just below there is a layer of mesophyll parenchyma joining up with the water-storage tissue (figs. 70, l''' and m''', and 71, l''' and m'''). A surface view of a bleached leaf embracing the epidermal, the palisade and the vascular bundle systems is shown in fig. 80. Between the water-storage tissue and the lower epidermis is a layer of mesophyll two or three cells deep (figs. 71, n''' and 72, n'''). The intercellular spaces in this are too small and regular to form a typical spongy tissue. The mesophyll cells are shown in tangential section in fig. 81. A typical spongy tissue has not been observed in any species of the Chenopodieæ, according to Solereder.

In the main rib of the leaf collenchyma cells join up the water-storage tissue and cells of the lower and upper epidermis, as shown in figs. 71, *b*, and 72, *b*, and the main rib projects out farther on the under side of the leaf than on the upper, there being more collenchyma in the under side of the main rib. Collenchyma serves as a strengthening tissue in the tip of the leaf and also in the tip of each lobe of the leaf, as is shown in fig. 82.

The venation of the leaf is mapped out in fig. 83, which is made from a whole leaf bleached and cleared by the method of Peace ('11). To hasten the removal of the abundant calcium oxalate crystals, the leaves treated were left over night in 10 per cent hydrochloric acid after being treated with 5 per cent potassium hydroxide solution. The leaves were then stained with safranin in a concentrated chloral hydrate solution; and the surplus stain having been washed out in distilled water, the leaf was bleached in chloral hydrate solution until just the vascular system retained the red color. The leaf venation is very irregular and does not form a close network. In each lobe of the leaf a main branch of the vascular system finds its termination (fig. 83).

The venation of the leaf ends blindly throughout the mesophyll (fig. 84), except at the edge of the leaf, where the ultimate endings are groups of tracheids extending out close to the epidermis (fig. 85). The ultimate endings of the venation stand on an average of .9 mm. apart in the greater part of the mesophyll of the leaf, but the tracheid endings at the edge of the leaf stand

about .5 mm. apart. The tracheids are of three kinds, spiral, annular, and reticulate (figs. 84, p'', q'', and r''; and 85, p'', q'', and r'').

The xylem, phloëm and border parenchyma cells of a vascular bundle of the leaf are shown in cross section in fig. 72. The border parenchyma cells in leaves, which were left in 5 per cent potassium hydroxide solution for bleaching, are shown in tangential section in fig. 79. The pits in the end walls of these elongated cells are not conspicuous in unbleached sections (fig. 86).

The vascular system of the petiole is made up of separate vascular strands. This is shown in the cross section of a petiole from the base upward in figs. 87 to 89, inclusive, in which the five vascular strands are mapped out. The cross section of the petiole in fig. 87 was cut from the base of the petiole; fig. 88, midway between the base and tip of the petiole; and fig. 89, from the tip of the petiole. Each vascular strand has a sheath of border parenchyma. A cross section of two of the vascular bundles of the petiole is shown in fig. 90, *j*. Petit (*fide* Solereder, '08) has found that isolated vascular bundles form the vascular system of the petioles in species which he examined in the genera *Artiplex, Blitium*, and *Chenopodium*.

In the figs. 91 to 95, inclusive, there is mapped out a series of portions of the cross sections of the stem from below the petiole attachment to a little above. The five leaf-trace bundles are mapped out in fig. 91. In fig. 92 the leaf traces are crossing out of the stem into the petiole. Successive steps in the closing of the leaf gap are shown in figs. 93, 94 and 95.

NATURE OF THE CELL CONTENTS.

The Stem.

Distributed through the protoplasts of the cells of the epidermis, and of the collenchyma and parenchyma of the primary cortex, there are quite a number of large globules (and many small globules) which stain like oil with Sudan III and alcannin (fig. 9, q'). Similar globules are present in the cells of the phloëm of primary vascular bundles, and of the phloëm and secondary medullary rays of the anomalous tissue. The globules in newly cut sections of formalin material, left in Sudan III for twenty-four hours, stained red; in alcannin, pink. Some of the globules in sections which had remained in xylene, chloroform or ether for twenty-four hours, and were then left in either of the two stains mentioned above, stained as before, but nearly all the globules

had been dissolved out. All the globules which stain like oil dissolved out in sections left in xylene, chloroform or ether for forty-eight hours. Certain of these globules stain evenly, but most of them stain unevenly. Usually a spherical core (ranging from 4 to 20 per cent of the volume of the globule), located in the center or at the side of each unevenly stained globule, stains a darker or lighter red than the rest of the globule. Two separate spherical cores were present in each of certain globules observed.

Saponification tests on fresh sections did not indicate the presence of saponifiable oil in the globules. The Tunmann reagent used for the tests was made up fresh, and was tested on castor-bean sections, the oil of which saponified. The test was repeated on freshly cut sections of stem, and more reagent was made available to the mounted sections by placing small strips of cork at the edge of the cover-slips, which were then sealed with wax (65 per cent beeswax and 35 per cent rosin), or by the use of hollow-ground slides. The slides were placed in the electric oven and examined daily. The globules, which stain like oil, dissolved out in from twenty-four to forty-eight hours, and no saponification was evident in sections examined with the aid of the microscope or polarizer.

The oil globules in sections steamed for eight hours and then left in Sudan III or alcannin for twenty-four hours stained like the globules in sections, newly cut from formalin material, left in either of the two stains for twenty-four hours. Evidently no substance in the globules escapes when the sections are steamed, for the globules average the same size as the globules in sections not steamed. Condensed vapor from steam, which had been passed over sections and then condensed on cold petri dishes, did not stain yellow when exposed to the vapors from heated iodine crystals, and the presence of violatile oil was not demonstrated.

The above tests indicate that an oil is present in the globules, but evidently not a volatile nor a saponifying oil.

In many of the cells containing globules staining like oil there are also greenish-yellow globules, which do not dissolve out after the sections have remained seven days in xylene, chloroform or ether, and which do not stain when the sections are left in Sudan III or alcannin for forty-eight hours (fig. 9, *r'*). These globules were tested for glucosides as follows: Sections were boiled in 5 cc. of Fehling's solution, and at first there was no change in the color of the reagent, nor could crystals of cuprous oxide be seen in these yellowish-green globules with the microscope; a precipi-

tate of cuprous oxide began to form after boiling for a minute or so; and upon further boiling a copious precipitate formed. Other sections mounted in Fehling's solution on hollow-ground slides were placed in the electric oven and examined daily. After twenty-four hours cuprous oxide crystals had formed, and for three days thereafter the number of crystals gradually increased and the globules disappeared. The slow reduction of two tests suggest the presence of glucosides in these globules.

The presence of resin was not indicated in sections which had been left in concentrated copper acetate solution for three weeks.

The blue stain characteristic of mucilage did not develop in free-hand sections placed in a solution of methylene blue in equal parts of alcohol, glycerine and water.

Tannin was not demonstrated in sections mounted in ferric chloride.

A few crystals of cuprous oxide were formed in the cells of the epidermis, and also in cells of the collenchyma, parenchyma, and starch sheath of the primary cortex, in sections mounted in Fehling's solution and heated just to the boiling point. Crystals of cuprous oxide were also formed in the phloëm cells of the primary vascular bundles. The presence of reducing sugar, probably grape sugar, was thus indicated by the immediate reduction of the reagent without boiling.

Starch was not generally found in the starch sheath; a slight amount of starch was found in region II; a few cells of the starch sheath in the main axis of the stem contained much starch.

The contents of cells of the phloëm of the primary vascular bundles and the phloëm of the anomalous tissue stain red in sections left in Millon's reagent for several hours in the electric oven. A yellow stain of these cell contents appeared in sections mounted in concentrated nitric acid, and the yellow color deepened when a drop of ammonium was added. The results of the two tests indicate the presence of proteins.

Large spherical aggregates of calcium oxalate crystals are present in the starch sheath cells, in the outer rows of cells of the pericycle, and in the pith cells, in all regions of stem; but are especially abundant in region III and below (fig. 9, *s*). The starch sheath cells and a few collenchyma cells of the primary cortex in region II are filled with masses of the crystals. Only one aggregate of crystals occurs in a single cell. A few of the pith cells in regions III and IV and the main axis contain a few or quite a number of single crystals (fig. 9, *t*). There are abundant clusters of these

crystals in the secondary medullary rays and pericycle cells in the zones of thin-walled anomalous tissue (designated as phloëm zones in this article). When sections mounted in distilled water on a slide were irrigated with a drop of hydrochloric acid, the crystals disappeared in several seconds without effervescence, indicating the presence of calcium oxalate. Jost ('08) states, many plants normally containing calcium oxalate have only a small amount or none present, when presented with not more than the indispensable minimum of $Ca(NO_3)_2$, according to Amar; or if presented with nitric acid in the form of an ammonium salt, according to Beneck. It is of interest to note here that Politis (*fide* Experiment Station Record, '12) draws the following conclusions from his research work on the origin and office of oxalate of lime in plants: "Oxalic acid, with its resulting calcium oxalate, has its origin in the cell in which the salt is found in crystalline form, and the acid is formed by oxidation of glycogen or amyloids."

Free-hand sections over one cell in thickness were tested for alkaloids, and sections soaked in an alkaloid solvent (one part of tartaric acid dissolved in twenty parts of alcohol for twenty-four hours and rinsed in distilled water for twenty-four hours were used as a control. No precipitate formed in sections mounted in potassium iodide-iodine, potassium permanganate, or ammonium molybdate. Sections were treated with picric acid and tannic acid, as suggested by Winterstein and Trier ('10), but no precipitate formed. No characteristic color developed with nitric acid or sulphuric acid to indicate the presence of alkaloids. No precipitations or color reactions occurred in the control sections treated with tartaric alcohol, nor was there any marked indication that cell contents had been dissolved out.

The Root.

Tests were made on the sections of the root as on the sections of the stem. Globules in the cells of the epidermis and primary cortex dissolved out in xylene or chloroform, and the globules of other sections stained red in Sudan III and pink in alcannin. The globules did not give a test for saponifying oil nor resin. A slight amount of reducing sugar was found in the cells of the pericycle, the phloëm and xylem parenchyma of the primary vascular bundles, and the secondary medullary rays and phloëm of the anomalous tissue. The presence of protein was indicated in the cell contents of the phloëm of the primary vascular bundles and the phloëm of the anomalous tissue by the red stain with Millon's

reagent. The characteristic yellow stain deepened when a drop of ammonium was added to sections which had been mounted in nitric acid. Clusters of crystals of calcium oxalate were numerous in the cells of the primary cortex, the pericycle, and the secondary medullary rays. No volatile oil, glucosides, mucilage, tannin, starch nor alkaloids were found to be present in the root.

The Leaf.

Similar tests were made on sections of the leaf. Certain globules which stain red in Sudan III and pink in alcannin, like oil, were present in the cells of the epidermis, and photosynthetic tissue (fig. 73, *q′*). These globules stain unevenly like similar globules in the stem. The globules are soluble in xylene, chloroform, and ether. Other tests did not indicate the presence of saponifying oil nor resin in these globules.

There are other globules, most of which are quite large, in the epidermal cells, which did not stain with Sudan III nor alcannin, and which were not soluble in xylene, chloroform, nor ether; but these globules in sections left in the electric oven formed crystals of cuprous oxide with Fehling's solution continuously for three days, the presence of glucosides thus being indicated (fig. 73, *r′*).

The presence of reducing sugar was demonstrated by the formation of cuprous oxide crystals in the cells of the phloëm and photosynthetic tissue when sections of the leaf in Fehling's solution were heated to the boiling point.

The characteristic stain of protein developed with Millon's reagent, or nitric acid with the addition of ammonium, in the cell contents of the phloëm of leaf sections tested.

Clusters of calcium oxalate crystals occur in great abundance in the border parenchyma cells of the veins, and the water-storage tissue. In a general drawing of a bleached leaf, the greater part of the leaf is darkened by the numerous crystals mapped out along the veins and veinlets of the leaf (fig. 96).

The other tests applied did not indicate the presence of volatile oil, mucilage, tannin, starch nor alkaloids in the leaf.

The Hairs of the Leaf and Stem.

In the cells of the basal portions of the clothing hairs (figs. 16, *q′*, and 77, *c″*,) and of the glandular hairs (figs. 17, *q′*, and 78, *c″*) of the stem and the leaf are globules which stain with Sudan III and alcannin.

There are more of such globules in the four cells of the terminal portion (figs. 17, *u′*, and 78, *u′*) of the glandular hairs than in the basal portion (figs. 17, *u′*, and 78, *u′*). In the terminal cell, and the cell just beneath, in certain of the glandular hairs are a few very large oil globules (fig. 78, *d″*) some of which have a volume thirty-six times as great as the other oil globules. The usual tests do not indicate the presence of saponifying oil, volatile oil nor resin in these globules. The cell contents of the terminal portion of the glandular hairs appear yellow in formalin material. In iodine solution, potassium iodide-iodine or chloroiodide of zinc a portion of these cell contents stain dark blue. The stain with iodine solution thus indicates the presence of starch.

The cell contents of the terminal portion of the glandular hairs did not dissolve out in 5 per cent potassium hydroxide in twenty-four hours or one week. After remaining twenty-four hours in concentrated potassium hydroxide solution all the oil globules and most of the cell contents had been dissolved out. Portions of the cell contents dissolved out in 10 per cent nitric acid and 10 per cent sulphuric acid. In concentrated sulphuric acid the cell contents are stained orange, and a part of the cell contents are dissolved out after 15 minutes. A part of the cell contents are dissolved out in 15 minutes in sections treated with concentrated nitric acid, but the cell contents do not change in color in this strength of the acid. Apparently only the oil globules are removed from hairs remaining in xylene, chloroform or ether for twenty-four hours or one week. The cell contents stain with safranin, and portions also stain with hæmatoxylin.

Some reducing sugar was present in the cells of the basal portions of both the clothing and glandular hairs.

The presence of glucosides, mucilage, tannin, protein, calcium oxalate or alkaloids was not demonstrated in either of the two types of hairs.

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DESCRIPTION OF PLATES.

PLATE I.

Fig. 1. A photograph of a main branchlet, showing the small leaves and the habit of branching.

PLATE II.

Fig. 2. Cross section of the stem in region I. (See fig. 29, *m''*); *a*, epidermis; *b*, collenchyma of primary cortex; *c*, parenchyma of primary cortex; *d*, starch sheath between the dotted and continuous line; *e*, outer area of the pericycle made up of small cells; *f*, inner area of the pericycle made up of large cells; *g*, primary medullary ray; *h*, pith; *i*, hair; *j*, primary vascular bundle. $\times$ 48.

Fig. 3. Cross section of the stem in region II. (See fig. 29, *o''*.) The woody cylinder is colored black, and the included phloëm groups and larger tracheæ are left white. The cell walls are cellulose in the area *e''*, which is the outer portion of the pericycle area *e*, and are lignified in the inner portion *e''*, of the pericycle area *e*. Corresponding parts lettered as in fig. 2: *k*, leaf-trace bundle in the pericycle. $\times$ 48.

Fig. 4. Cross section of the stem in region III. (See fig. 29, *p''*). The woody cylinder is colored black, and the included phloëm groups and larger tracheæ are left white. Corresponding parts lettered as in fig. 2: *b*, leaf-trace bundle; *l*, inner border of the innermost anomalous xylem ring; *m*, anomalous xylem; *n*, active arc of secondary meristem. $\times$ 30.

Fig. 5. Cross section of the stem in region IV. (See fig. 29, *r''*.) The cell walls of the primary medullary rays, and regions *e''* and *f*, of the pericycle in this section, are not lignified except in the outer portion of the pericycle area *e''* (this outer portion of *e''*, colored black, being included in the

woody cylinder). Corresponding parts lettered as in figs. 2 and 4: *n*, one of the several active arcs of secondary meristem in the figure which anastomose radially and tangentially with the arcs, in the corresponding ring of secondary arcs, in the region of stem below; *o*, area of one to six rows of very large parenchyma cells of the primary cortex around the stem; *p*, anomalous zylem zone; *q*, zone of anomalous tissue, designated as a phloëm zone in this article; *r*, secondary medullary ray; *s*, anomalous phloëm; *t*, pericycle cells in outer portion of a zone of anomalous tissue, designated as a phloëm zone in this article. × 18.

PLATE III.

FIG. 6. Cross section of the stem in region V. (See fig. 29, *s''*.) Corresponding parts lettered as in fig. 5: *u*, radial strip of xylem anastomosing from one anomalous xylem zone to another; *a*, lenticel; *b'*, cork; *c'*, xylem, the cell walls of which are not lignified except those of the tracheæ included in the innermost anomalous xylem zone; *d'*, xylem of usual structure included in the innermost xylem zone; *f'*, bast fiber; *g'*, radial strip of tissue anastomosing from one phloëm zone to another. × 9.

FIG. 7. Cross section of the stem in region I. (See fig. 29, *m''*.) Corresponding parts lettered as in fig. 2: *h'*, phloëm of primary vascular bundle; *i'*, procambium of primary vascular bundle; *j'*, primary xylem of primary vascular bundle; *k'*, cuticle; *l'*, chloroplast. × 225.

FIG. 8. Cross section of the stem in region II. (See fig. 29, *o''*.) Corresponding parts lettered as in figs. 2 to 7, inclusive: *m'*, secondary phloëm of primary vascular bundle; *n'*, cambial layer of primary vascular bundle; *o'*, secondary xylem of primary vascular bundle; *p'*, intercellular space. × 225.

PLATE IV.

FIG. 9. Cross section of the stem in region III. (See fig. 29, *p''*.) Corresponding parts lettered as in fig. 8: *k*, parenchyma of primary cortex between collenchyma of the rib and the starch sheath; *q'*, oil globule; *r'*, glucoside globule; *s'*, mass of calcium oxalate crystals in a pith cell; *t'*, single crystals of calcium oxalate in a pith cell. × 225.

FIG. 10. Outer portion of cross section of the stem in region IV. (See fig. 29, *r''*.) Corresponding parts lettered as in fig. 8: *o*, area of one to six rows of very large parenchyma cells of the primary cortex around the stem; *p*, anomalous xylem zone; *q*, anomalous phloëm zone; *r*, secondary medullary ray; *s*, anomalous phloëm; *t*, pericycle cells in the outer area of a zone of anomalous tissue, designated as a phloëm zone in this article; *u*, radial strip of xylem anastomosing from one anomalous xylem zone to another. × 225.

PLATE V.

FIG. 11. Inner portion of a cross section of the stem in region IV. (See fig. 29, *r''*.) Corresponding parts lettered as in fig. 8. × 225.

FIG. 12. Surface view of lengthened epidermal cells of a rib of the stem in region III, showing type and frequency of stomata. × 225.

FIG. 13. Radial longitudinal section of the epidermis of the stem in region III: *k'*, cuticle. × 225.

FIG. 14. Surface view of the epidermal cells between the ribs of the stem in region III, showing type and frequency of stomata. × 225.

FIG. 15. Portion of radial longitudinal section of the stem in region III, showing epidermis, *a*, the parenchyma of the primary cortex, *e*, and the starch sheath, *d*: *k'*, cuticle; *p'*, intercellular space. × 225.

FIG. 16. Clothing hair of the epidermis of the stem in region I: *a*, basal cell; *k'*, cuticle; *q'*, oil globule; *u'*, terminal portion; *a''*, basal portion of one or more short cells above the basal cell. × 330.

FIG. 17. Glandular hair of the epidermis of the stem in region I: *a*, basal cell; *k'* cuticle; *u'*, terminal portion; *a''*, basal portion consisting of two or more short cells; *b''*, dense cell contents in terminal portion; *c''*, small oil globule; *d''*, large oil globule. × 225.

FIG. 18. Longitudinal section of the collenchyma of the primary cortex of the stem in region III. × 225.

FIG. 19. Portion of cross section of the stem in region V, showing cork cells, *b'*: *d*, starch sheath; *o*, area of one to six rows of very large parenchyma cells of the primary cortex around the stem; *q'*, bast fiber. × 225.

FIG. 20. Portion of cross section of the stem in region V, showing lenticel, *b'*: *a*, epidermis; *c*, parenchyma of the primary cortex; *d*, starch sheath; *o*, area of one of six rows of very large parenchyma cells of the primary cortex around the stem; *f'*, bast fiber; *k'*, cuticle; *p'*, intercellular space; *f''*, stoma. × 225.

PLATE VI.

FIG. 21. Portion of longitudinal section of the stem in region III: *d*, starch sheath; *e'*, outer portion of the pericycle, the cell walls of which have not lignified, corresponding to the area of pericycle *e'* in cross section, fig. 9. × 225.

FIG. 22. Portion of cross section of the stem in region V to show veriation in location of bast fibers in the pericycle: *d*, starch sheath; *o*, portion of area of one to six rows of very large parenchyma cells of the primary cortex around the stem; *f'*, bast fibers; *e'*, outer area of the pericycle, the cell walls of this area not having lignified. × 225.

FIG. 23. Longitudinal section of bast fiber of medium length, from the outer portion of the pericycle of the stem in region IV, corresponding in location to the area of pericycle *e'* in cross section, fig. 9. × 225.

FIG. 24. Macerated wood fibers of medium size from the anomalous xylem of the stem in region IV. × 225.

FIG. 25. Longitudinal section of cells in the central portion of the pericycle from region III of the stem, corresponding to the area of pericycle, *e''*, fig. 10, in region IV. × 225.

FIG. 26. Portion of cross section of the stem in region V, showing the areas of pericycle *e''* and *f*, and cells of the inner portion of the anomalous xylem zone, *c'*, the cells of which in this region of stem resemble pith in shape in cross section: *q*, tissue designated as an anomalous phloëm zone in this article; *r*, secondary medullary ray; *s*, anomalous phloëm; *t*, pericycle cells in the outer part of the tissue designated as an anomalous phloëm zone in this article; *c'*, anomalous xylem having cellulose walls and located in the

innermost anomalous xylem zone; *d'*, anomalous xylem of the usual structure in the outer portion of the innermost anomalous xylem zone. × 225.

FIG. 27. Longitudinal section of primary medullary ray cells from region III of the stem. × 225.

FIG. 28. Longitudinal section of pith cells from region III of the stem. × 225.

PLATE VII.

FIG. 29. Diagram of a longitudinal section of the main axis of the stem to show the location of the five regions of stem, the broken leaf traces of region V and below, and the anomalous xylem-phloëm zones; *j*, primary vascular bundle; *n*, arcs of secondary meristem anastomosing radially with the arcs, in the corresponding ring of secondary arcs, in the region of stem below; *p*, anomalous xylem zone; *q*, tissue designated in this article as an anomalous phloëm zone; *u*, radial strip of xylem anastomosing from one anomalous xylem zone to another; *g'*, radial strip of tissue anastomosing from one anomalous phloëm zone to another; *h''*, fruit; *i''*, leaf; *j''*, branch; *k''*, region of primordial meristem; *l''*, procambium; *m''*, region I; *n''*, region of the stem for fig. 31; *o''*, region I; *p''*, region III; *q''*, region of the stem for figs. 50 and 51; *r''*, region IV; *s''*, region V; *t''*, leaf trace of leaf retained; *u''*, broken leaf trace.

FIG. 30. Primary vascular bundle in the formation in region I of the stem: *f*, inner area of pericycle; *g*, primary medullary ray; *h*, pith; *h'*, primary phloëm; *i'*, procambium; *j'*, primary xylem; *a'''*, water tube.

FIG. 31. Cross section of the stem just below region I (location shown in fig. 29, *n''*), showing young leaf trace bundle, *k*, in pericycle. Corresponding parts lettered as in fig. 8. × 225.

FIG. 32. Primary vascular bundle with cambial layer from region II of the stem. Corresponding parts lettered as in fig. 8. × 330.

FIG. 33. Longitudinal section of sieve tubes from secondary phloëm of primary vascular bundle in region III of the stem. × 330.

FIG. 34. Longitudinal section of companion cells, *b'''*, and phloëm parenchyma *c'''*, of a primary vascular bundle in region III of the stem. × 330.

FIG. 35. Primary vascular bundle, in which the cambial layer is no longer active, in region III of the stem. Corresponding parts lettered as in fig. 32: *d'''*, sieve tube having thickened cell walls; *f'''*, sieve tube with cell walls not thickened. × 330.

FIG. 36. Longitudinal section of a small spiral tracheal tube from primary xylem in region III of the stem. × 225.

FIG. 37. Longitudinal section of larger spiral tracheal tube from primary xylem in region III of the stem. × 225.

FIG. 38. Longitudinal section of annular tracheal tube of medium size from primary xylem in region III of the stem. × 225.

FIG. 39. Longitudinal section of pitted tracheal tube of medium size from a primary vascular bundle in region III of the stem. × 225.

FIG. 40. Longitudinal section of reticulate tracheal tube of medium size from a primary vascular bundle in region III of the stem. × 225.

FIG. 41. Longitudinal section of wood parenchyma from secondary xylem of primary vascular bundle in region III of the stem. × 225.

FIG. 42. Longitudinal section of pitted fiber tracheids from the secondary xylem of a primary vascular bundle in region III of the stem. × 225.

PLATE VIII.

FIG. 43. Primary vascular bundle from region IV of the stem. Corresponding parts lettered as in fig. 32. × 330.

FIG. 44. Older leaf-trace bundle in the pericycle of the stem in region IV. Corresponding parts lettered as in fig. 32. × 330.

FIG. 45. Portion of cross section of the stem in region V, showing primary medullary ray cells which, in this region of stem and below, resemble pith cells in shape and nature of cell walls: *j*, portion of primary vascular bundle. × 225.

FIG. 46. Longitudinal section of cells in a portion of the pericycle of the stem in region III corresponding in location to the area of pericycle *e''*, fig. 9. × 225.

FIG. 47. Portion of a cross section of the stem in region III: *d*, starch sheath; *e'*, outer area of pericycle; *e''*, central area of the pericycle; *n*, active arc of secondary meristem; *f'*, bast fiber. × 330.

FIG. 48. Portion of a cross section of the stem in region III; *d*, starch sheath; *e'*, outer area of the pericycle; *e''*, central area of the pericycle; *k*, leaf-trace bundle in the pericycle; *n*, active arc of secondary meristem. × 330.

FIG. 49. Portion of a cross section of the stem in region III: *d*, starch sheath; *e'*, outer area of the pericycle; *e''*, central area of the pericycle; *f*, inner area of the pericycle; *m*, anomalous xylem; *n*, active arc of secondary meristem; *s*, anomalous phloëm. × 330.

PLATE IX.

FIG. 50. Cross section of the stem between regions III and IV (location shown in fig. 29, *q''*). Corresponding parts lettered as in fig. 6: *l*, inner border of innermost anomalous xylem zone. × 48.

FIG. 51. Cross section of the stem between regions III and IV (location shown in fig. 29, *q''*). Corresponding parts lettered as in fig. 2: *j*, primary vascular bundle; *o*, portion of area of one to six rows of very large parenchyma cells of the primary cortex around the stem; *p*, anomalous xylem zone; *q*, anomalous phloëm zone; *r*, secondary medullary ray cell; *s*, anomalous phloëm; *t*, pericycle cells in outer part of area of tissue designated in this article as an anomalous phloëm zone; *u*, radial strip of anomalous xylem located similar to the strip of xylem anastomosing from one anomalous xylem zone to another in fig. 10, *u*; *p'*, intercellular space; *n''*, area of anomalous tissue, including a radial strip of anomalous xylem and an anomalous phloëm group just exterior; *o''*, long radial strip of anomalous xylem; *p''*, area of anomalous tissue, including a radial strip of anomalous xylem and a secondary medullary ray between the anomalous phloëm groups. × 225.

FIG. 52. Portion of cross section of stem in region IV; to show arc of secondary meristem, *n*, becoming active to form the fourth xylem-phloëm

zone; *d*, starch sheath; *s*, anomalous phloëm; *e'*, outer area of the pericycle; *p*, anomalous xylem zone; *f'*, bast fiber. × 330.

FIG. 53. Portion of a cross section of stem in region V, showing varied structure of the innermost anomalous xylem zone; *p*, anomalous xylem zone; *q*, anomalous phloëm zone; *r*, secondary medullary ray; *s*, anomalous phloëm; *t*, pericycle cells in outer part of area of tissue designated in this article as an anomalous phloëm zone; *m''*, tracheal tube; *n''*, wood parenchyma cell bordering a tracheal tube; *o''*, wood fiber; *p''*, tissue of inner 20 per cent of the anomalous xylem zone, composed entirely of wood fibers; *q''*, tissue of outer 80 per cent of the anomalous xylem zone composed of wood parenchyma and tracheæ. × 225.

FIG. 54. Longitudinal section of cells in the portion of the innermost anomalous xylem zone of the stem in region V, which correspond to the cells in the area, *c'*, fig. 25, but the cells of which have lignified walls and resemble pith cells in shape in cross section. × 225.

FIG. 55. Cross section of cells of anomalous xylem (shown in longitudinal section in fig. 54). × 225.

FIG. 56. Portion of cross section of stem in region V, showing strip of anomalous xylem, *u*, including a water tube, *M''*, and anastomosing from one anomalous xylem zone to another; *p*, anomalous xylem zone; *q*, anomalous phloëm zone; *r*, secondary medullary ray; *s*, anomalous phloëm; *t*, pericycle cells in outer part of tissue designated as a phloëm zone in this article. × 225.

FIG. 57. Portion of cross section of stem in region V, showing portion of the innermost anomalous xylem zone having wood fibers rectangular or almost square and arranged regularly in radial rows: *a'''*, water tube. × 225.

PLATE X.

FIG. 58. Portion of a cross section of the stem in region V, showing *g'''*, radial row of cells, having a radial dimension two to four times as great as their tangential dimension, in the anomalous xylem-phloëm zones. The radial row of cells consists of *h'''*, pericycle cells, and *a'''*, secondary medullary ray cells, in the anomalous phloëm zones; and of *j'''*, cells, which resemble wood parenchyma in size and proportion, in the xylem zones: *p*, anomalous xylem zone; *q*, zone of tissue designated in this article as an anomalous phloëm zone; *r*, secondary medullary ray; *s*, anomalous phloëm; *t*, pericycle cells in outer area of zone of anomalous tissue, designated in this article as a phloëm zone; *u*, radial strip of xylem anastomosing from one anomalous xylem zone to another; *g'*, radial strip of tissue anastomosing from one anomalous phloëm zone to another. × 225.

FIG. 59. Longitudinal section of a portion of pericycle tissue, located in the outer part of a zone of tissue, designated as an anomalous phloëm zone in this article, and corresponding in location to the area of tissue, *t*, in cross section, fig. 57. × 225.

FIG. 60. Longitudinal section of anomalous tissue, corresponding in location to the strip of anomalous tissue, in cross section in fig. 58: *g'''*, radial strip of tissue anastomosing from one anomalous phloëm zone to another. × 225.

FIG. 61. Cross section of the root in region I: *c*, primary cortex; *f*, pericycle; *g*, primary medullary ray; *j*, xylem of primary vascular bundle; *b'*, cork; *m'*, phloëm of primary vascular bundle; *m''*, tracheal tube. × 48.

FIG. 62. Cross section of the root in region II. Corresponding parts lettered as in fig. 61: *p*, anomalous xylem zone; *q*, zone of tissue designated in this article as an anomalous phloëm zone; *r*, secondary medullary ray; *s*, anomalous phloëm; *t*, pericycle cells in outer part of zone of tissue designated in this article as a phloëm zone. × 48.

PLATE XI.

FIG. 63. Cross section of the root in region III. Corresponding parts lettered as in fig. 62: *n*, active arc of secondary meristem. × 48.

FIG. 64. Cross section of the root in region IV. Corresponding parts lettered as in fig. 63: *g'''*, radial row of cells, having a radial dimension two to four times their tangential dimension, in the anomalous xylem-phloëm zones, and having cellulose cell walls. × 30.

PLATE XII.

FIG. 65. Cross section of the root in region V. Corresponding parts lettered as in fig. 64. × 9.

FIG. 66. Cross section of the root in region I. Corresponding parts lettered as in fig. 62. × 225.

FIG. 67. Cross section of the root in region II. Corresponding parts lettered as in fig. 62: *g'''*, radial row of cells, having a radial dimension two to four times as great as their tangential dimension, in the anomalous xylem-phloëm zones.

PLATE XIII.

FIG. 68. Cross section of the root in region III. Corresponding parts lettered as in fig. 62. × 225.

FIG. 69. Cross section of the root in region IV. Corresponding parts lettered as in fig. 62: *m''*, inner 20 per cent of anomalous xylem zone, made up entirely of wood fibers; *n''*, outer 80 per cent of the anomalous xylem zone, of the usual structure found in anomalous xylem zones of the stem. × 225.

FIG. 70. Portion of cross section of the root in region III, showing arc of secondary meristem, *n*, in the pericycle, *f*. × 330.

PLATE XIV.

FIG. 71. Cross section of the leaf mapping out the zones of tissue: *a*, epidermis; *b*, collenchyma; *c*, photosynthetic tissue; *d*, water-storage tissue; *e*, border parenchyma; *f*, vascular elements, *m'''*, lobe of the leaf. × 48.

FIG. 72. Portion of cross section of the leaf through the main rib. Corresponding parts lettered as in fig. 71: *k'*, cuticle: *m'*, phloëm; *o'*, xylem; *p'*, intercellular space; *d'''*, sieve tube having thick walls; *e'''*, palisade layer of the photosynthetic tissue; *m'''*, mesophyll parenchyma just beneath the palisade layer; *n'''*, mesophyll parenchyma located between the water-storage tissue and the lower epidermis. × 330.

PLATE XV.

FIG. 73. Portion of cross section of the leaf, showing structure between the bases of two lobes on one side of the leaf. Corresponding parts lettered as in fig. 72: *q′*, oil globule; *r′*, glucoside globule; *s′*, mass of calcium oxalate crystals in a cell of the water-storage tissue; *f″*, stoma. × 330.

FIG. 74. Surface view of cells of the upper epidermis, showing type and frequency of stomata. × 225.

FIG. 75. Surface view of cells of lower epidermis, showing type and frequency of stomata. × 225.

FIG. 76. Surface view of the lengthened cells of the upper epidermis over the main rib, showing type and frequency of stomata. × 225.

FIG. 77. Clothing hairs of the epidermis of a very young leaf: *a*, basal cell; *k′*, cuticle, *q′*, oil globule; *u′*, terminal portion; *a″*, basal portion of one or more short cells above the basal cell. × 330.

FIG. 78. Glandular hairs of the epidermis of a very young leaf: *a*, basal cell; *k′*, cuticle; *l′*, dense cell, contents in the terminal spherical cell; *u′*, terminal portion; *a″*, basal portion; *c″*, small oil globule; *d″*, large oil globule. × 330.

PLATE XVI.

FIG. 79. Portion of a tangential section of a leaf bleached in 5 per cent potassium hydroxide: *d*, water-storage tissue; *e*, spiral tracheal tube of the vascular elements; *n‴*, border parenchyma cells having end walls pitted. × 330.

FIG. 80. Surface view of a bleached leaf, embracing the epidermal, the palisade and the vascular bundle systems. × 330.

FIG. 81. Portion of a tangential section of the leaf, showing cells of the epidermis, *a*, and mesophyll parenchyma, *n‴*, under the water-storage tissue: *k′*, cuticle; *p′*, intercellular space. × 330.

FIG. 82. Portion of a cross section of the leaf to show collenchyma in the tip of a lobe of the leaf: *a*, epidermis; *b*, collenchyma; *k′*, cuticle; *n‴*, mesophyll parenchyma. × 80.

PLATE XVII.

FIG. 83. Bleached leaf, showing venation: *d*, water-storage tissue between the three largest veins. × 17.5.

FIG. 84. Blind ending of the venation in the midst of the mesophyll, showing spiral, *p″*, annular, *q″*, and reticulate, *r″*, tracheids. × 330.

FIG. 85. Groups of spiral, *p″*, annular, *q″*, and reticulate, *r″*, tracheids, which extend out close to the expidermis and serve as the ultimate endings of the venation at the edge of the leaf. × 330.

FIG. 86. Portion of a tangential section of the leaf to show pits in end walls of border parenchyma cells, *o‴*, are not conspicuous in unbleached sections: *j*, vascular elements. × 330.

FIGS. 87-89. A series of cross sections of the petiole of the leaf proceeding upward: *a*, epidermis; *b*, collenchyma; *c*, photosynthetic tissue; *d*, water-storage tissue; *e*, border parenchyma; *p″*, *q″*, *r″*, *s″*, and *t″*, five vascular bundles of the petiole.

FIG. 87. Cross section from the base of the petiole. × 48.

FIG. 88. Cross section midway between the base and the tip of the petiole. × 48.

FIG. 89. Cross section from the tip of the petiole, showing vascular-bundle strands, o'' and u'', which are branches of p'' and t'', respectively. ×48.

FIG. 90. Portion of a cross section midway between the base and the tip of the petiole, showing two vascular bundles, j: d, water-storage tissue; e, border parenchyma; d''', sieve tube having thick walls. × 330.

PLATE XVIII.

FIGS. 91 to 94, inclusive. A series of cross sections of the stem in region IV, from below the petiole attachment to a little above. The anomalous tissue is colored black.

FIG. 91. Section of the stem just below the petiole attachment, showing the five leaf-trace bundles, p'', q'', r'', s'' and t'', about to enter the petiole. Corresponding parts lettered as in fig. 2. × 48.

FIG. 92. p'', q'', r'', s'' and t'' are in the leaf-trace gap, and are entering the petiole. × 48.

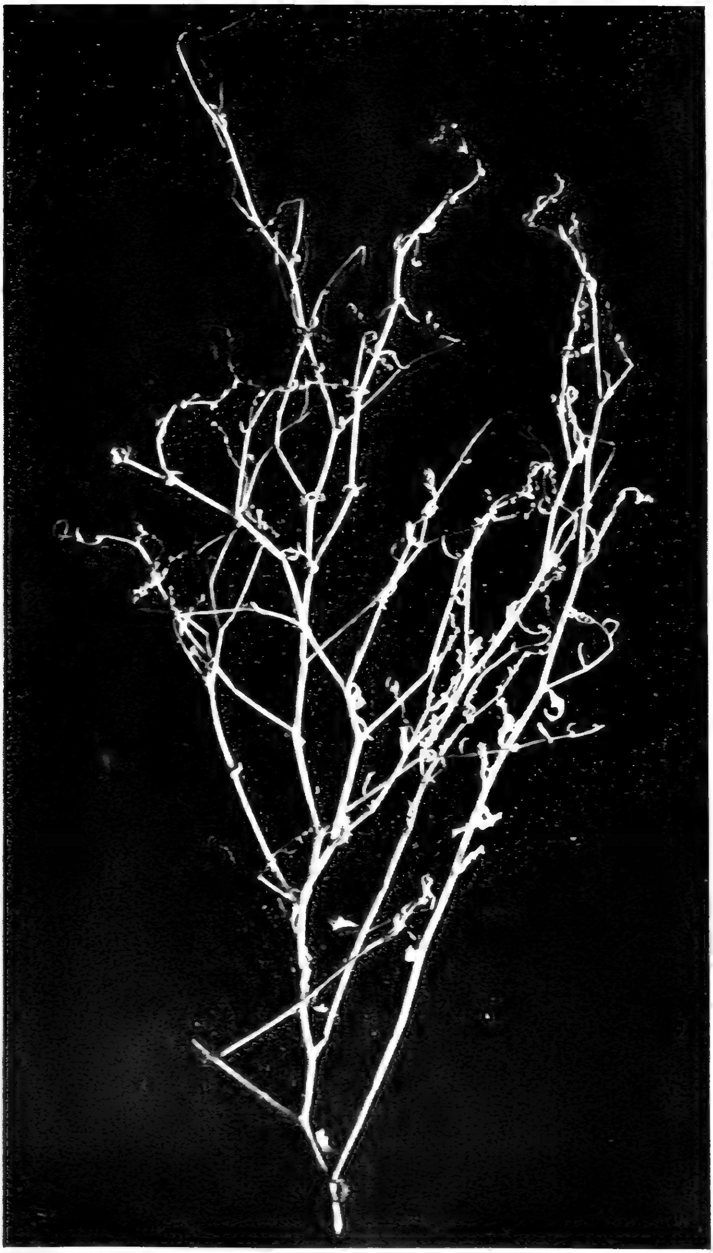
FIG. 93. p'', q'', r'', s'' and t'' have left the leaf-trace gap, p'''. × 48.

FIG. 94. p''', leaf-trace gap partially closed. × 48.

PLATE XIX.

FIG. 95. Leaf-trace gap closed in a section of the stem just above the petiole attachment. × 48.

FIG. 96. General drawing of a leaf, bleached in 5 per cent potassium hydroxide, to show the abundance of calcium oxalate crystals occurring in the border parenchyma of the veins, and the water-storage tissue. The areas colored black represent the location of the masses of crystals.



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CYCLOLOMA ATRIPLICIFOLIUM.
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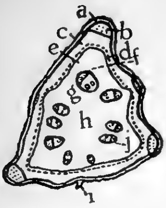
PLATE II.



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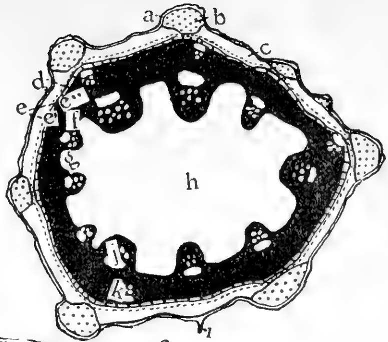

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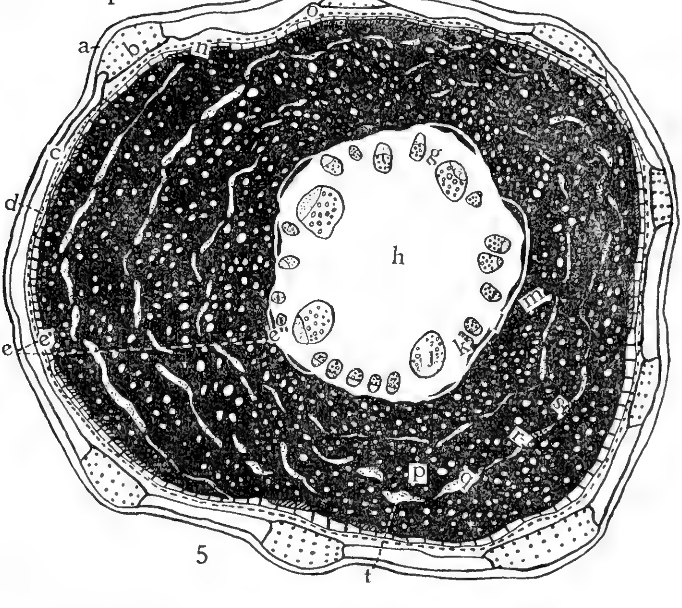

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Cycloloma Atriplicifolium.
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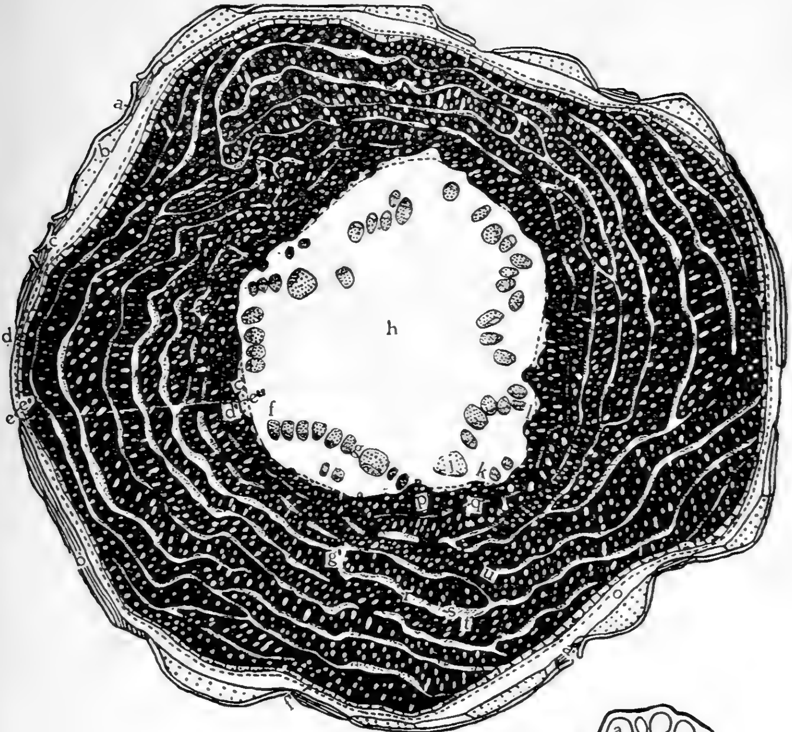
PLATE III.



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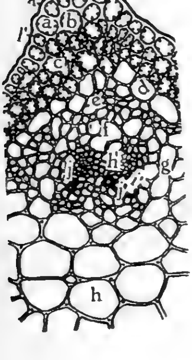

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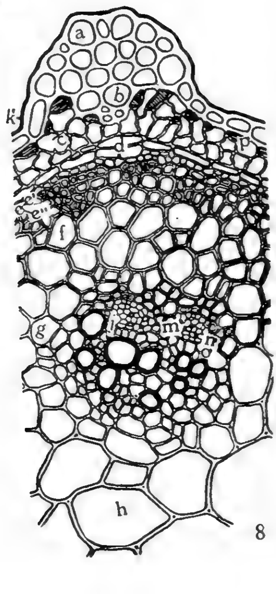

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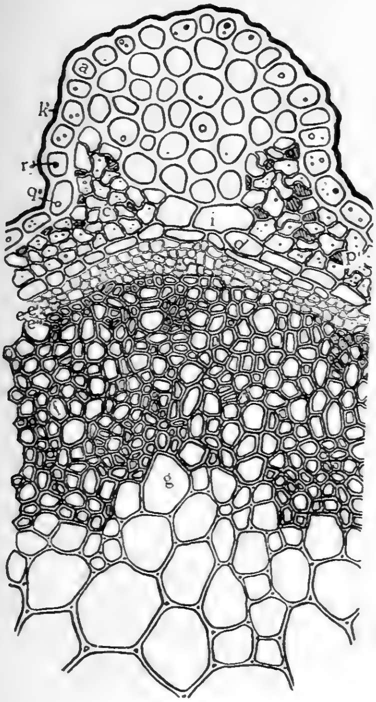

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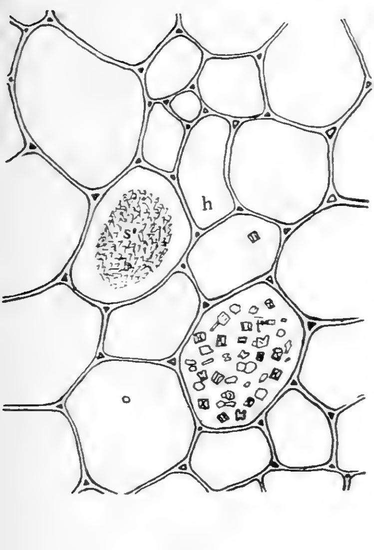

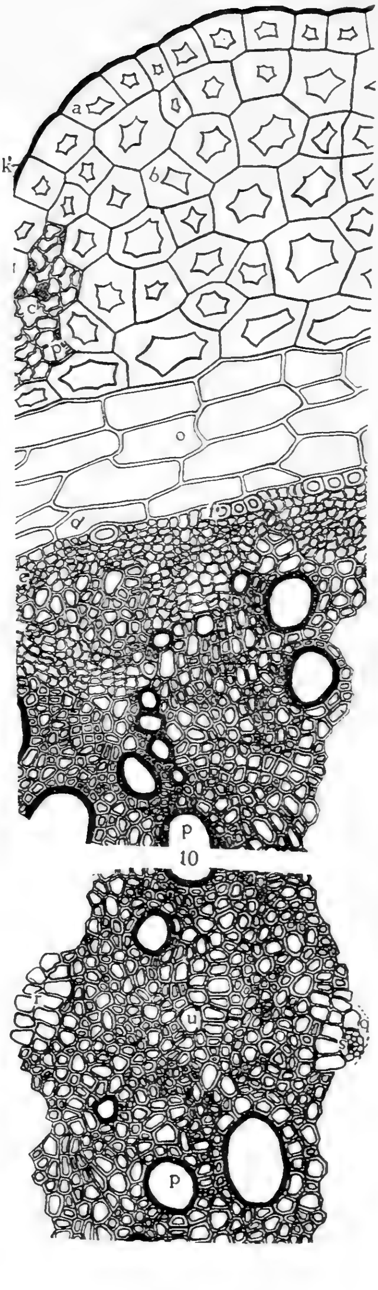

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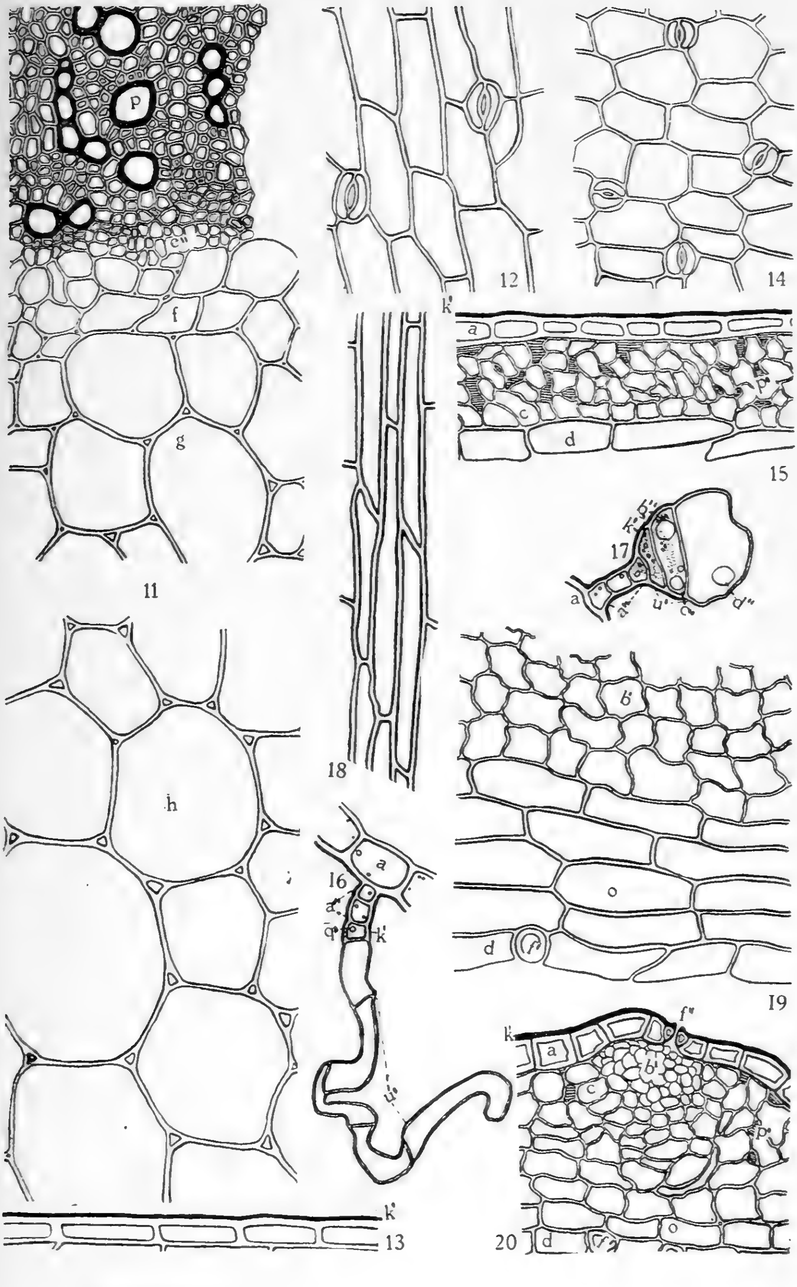

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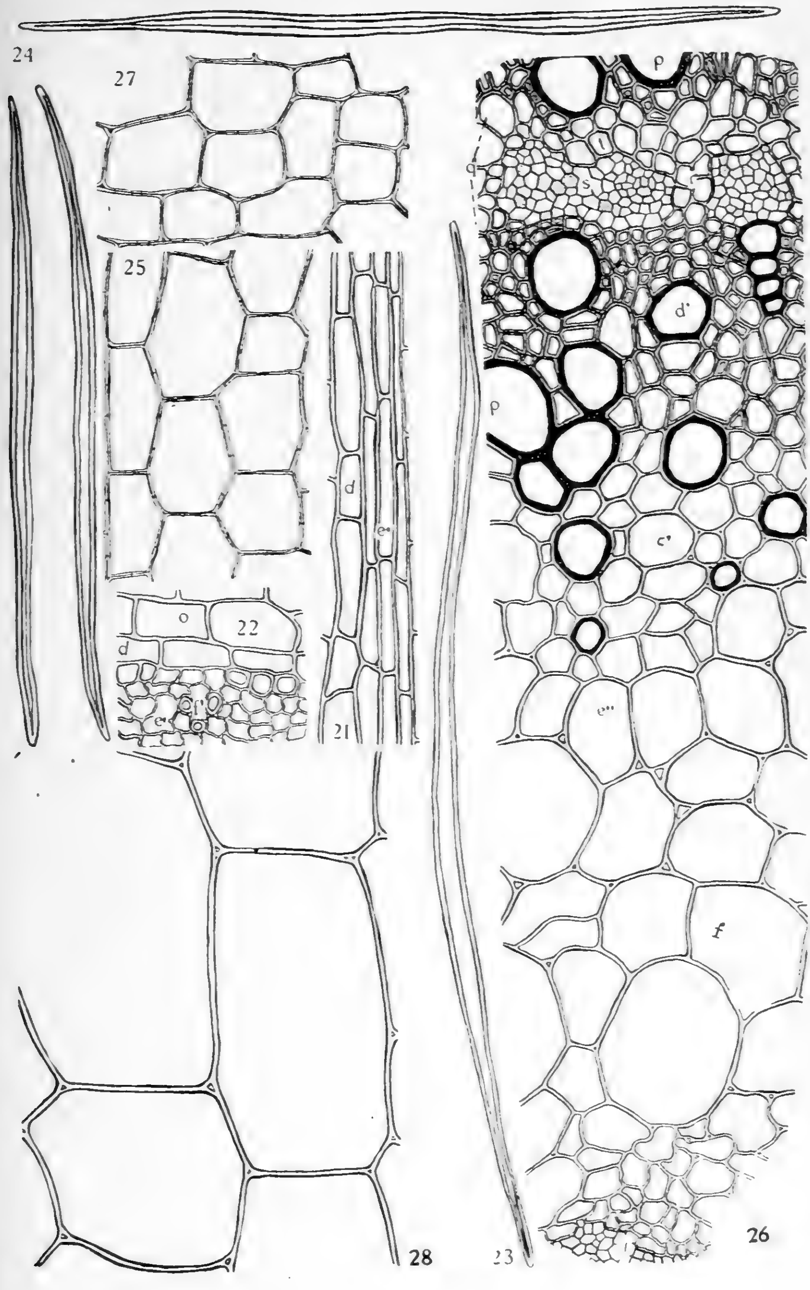
PLATE VI.



CYCLOLOMA ATRIPLICIFOLIUM.

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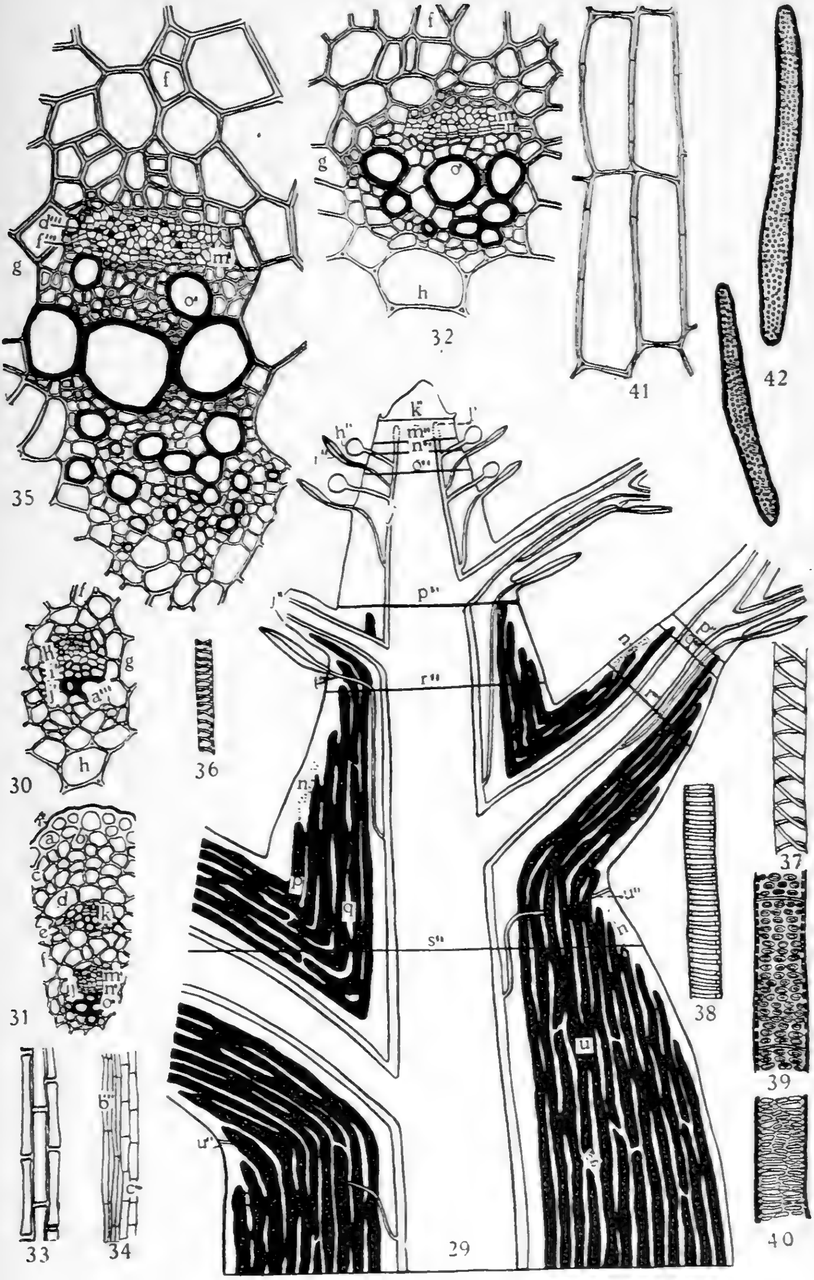
PLATE VII.



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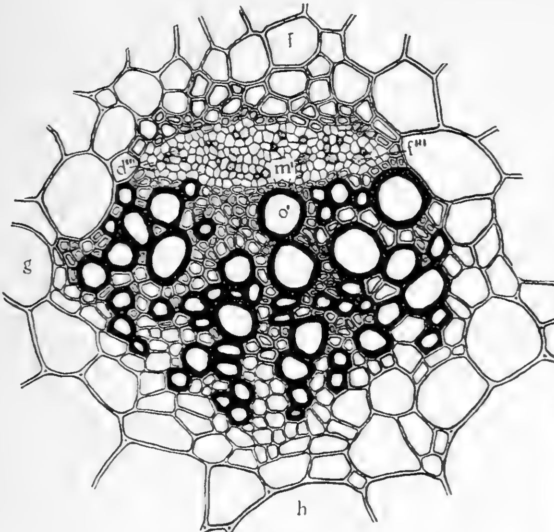

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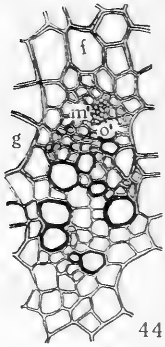

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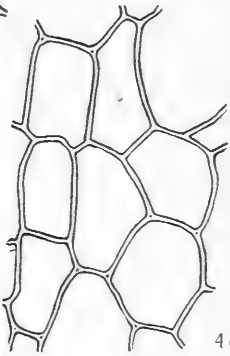

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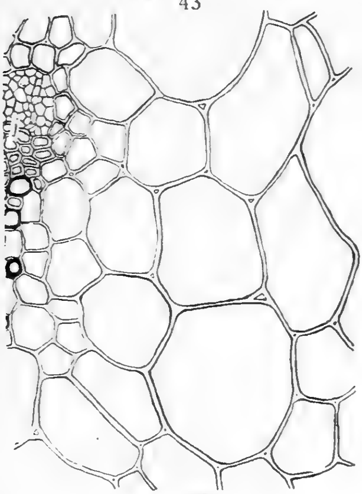

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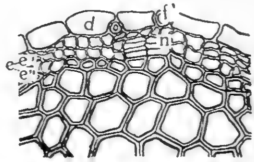

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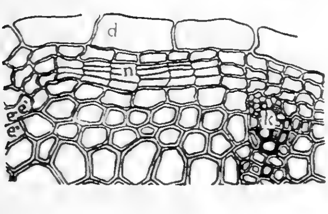

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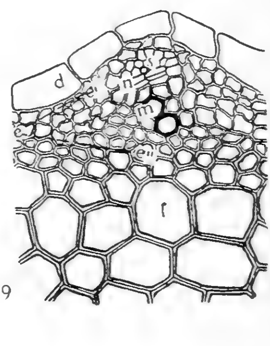

49

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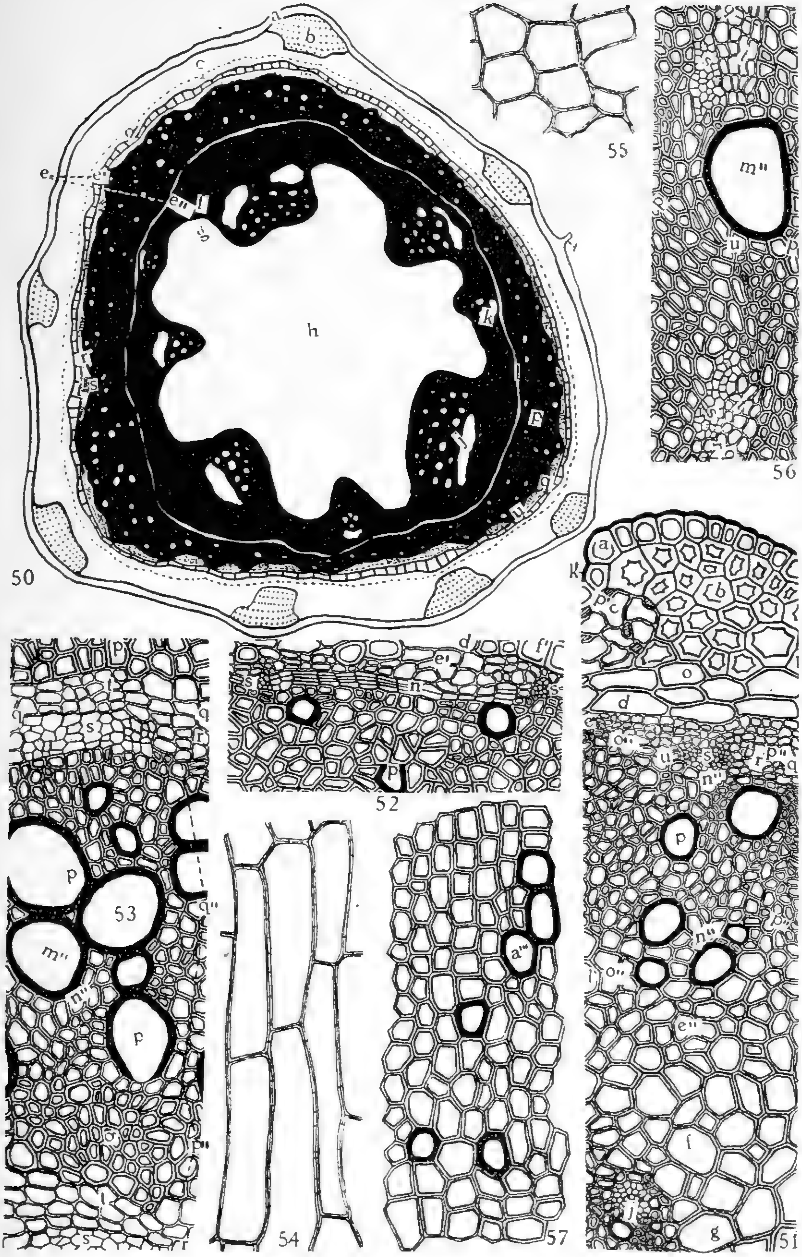
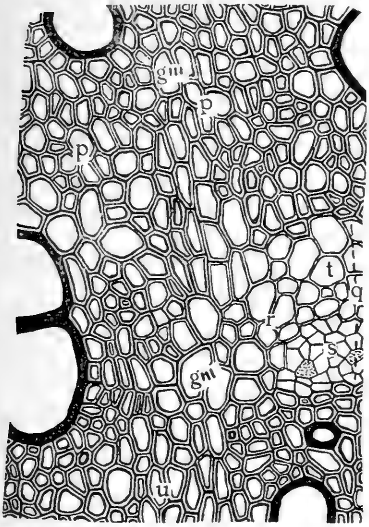
PLATE IX.





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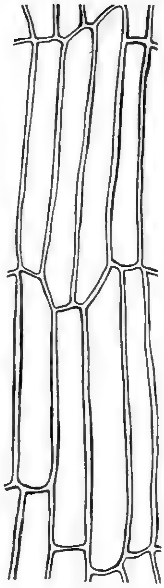

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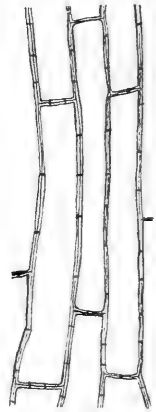

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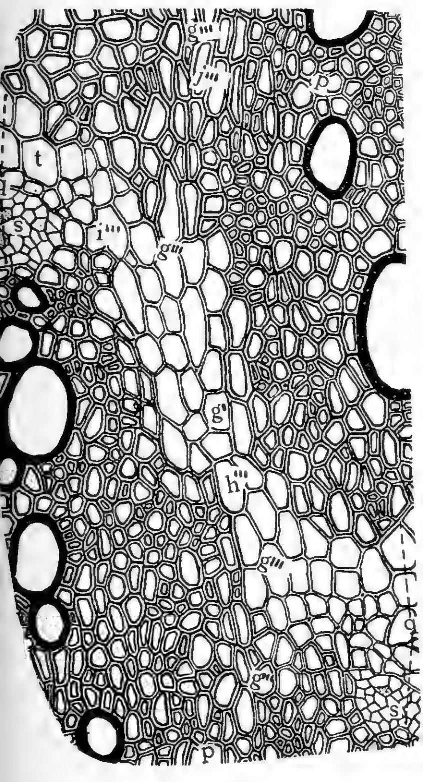

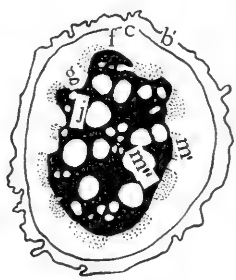

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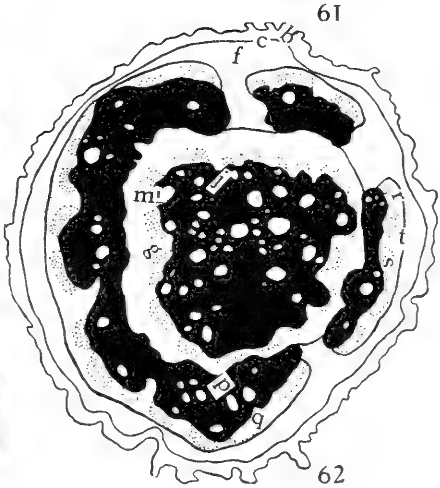

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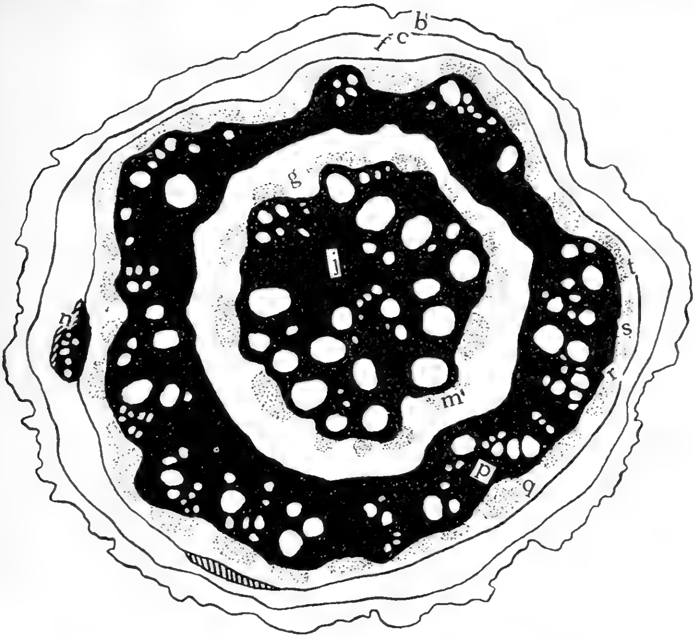

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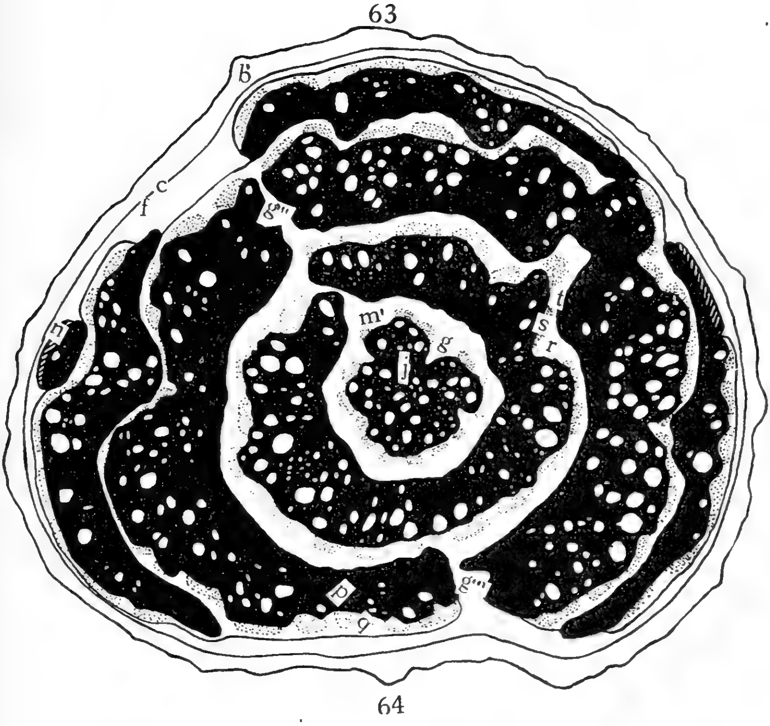

64

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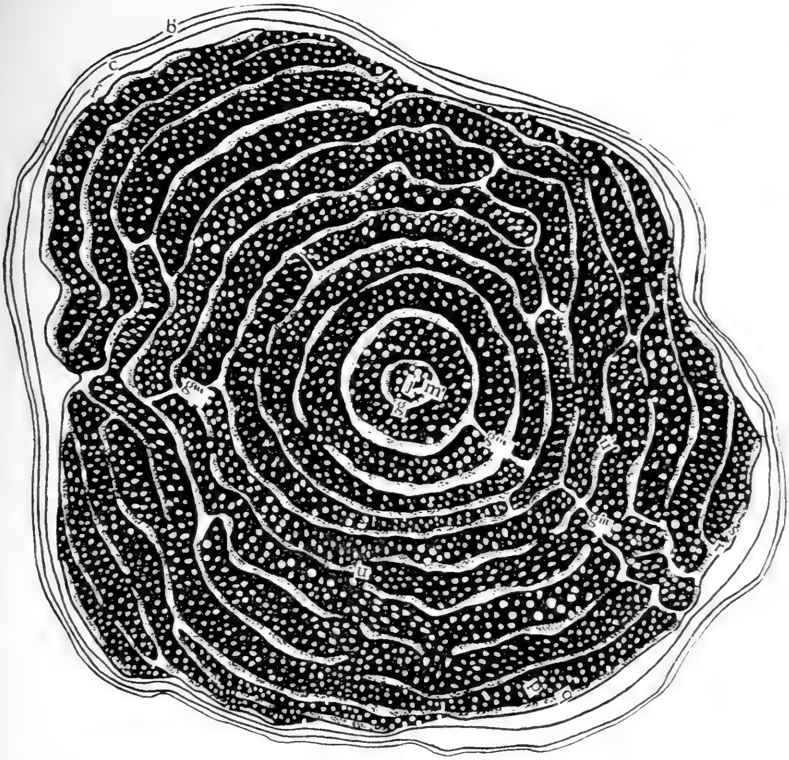
PLATE XII.



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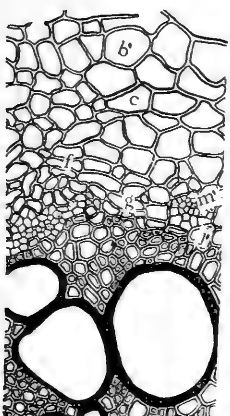

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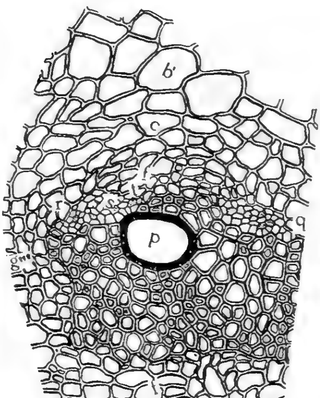

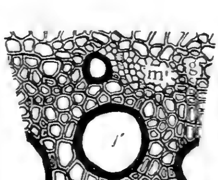

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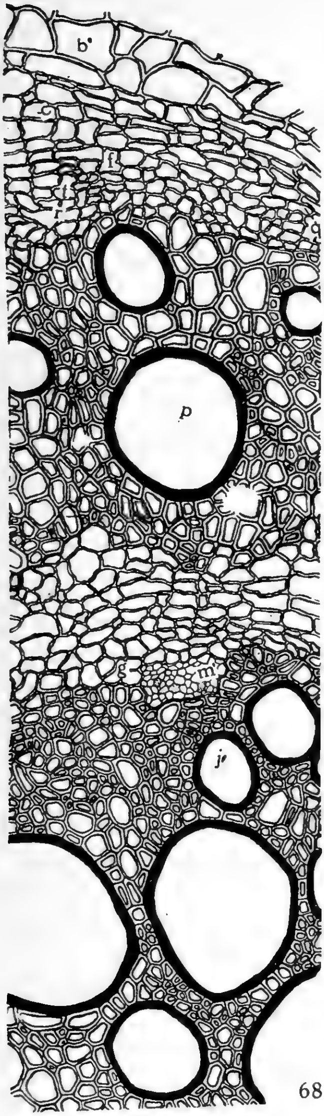

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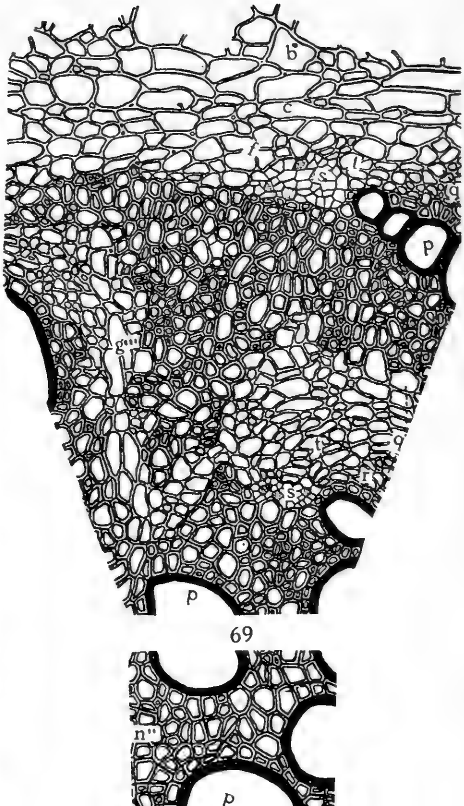

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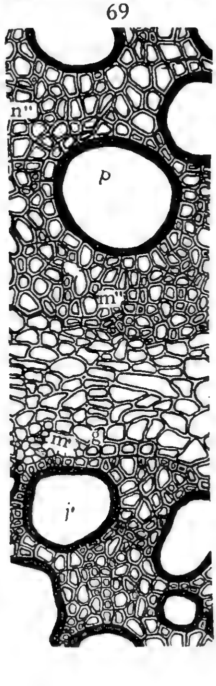

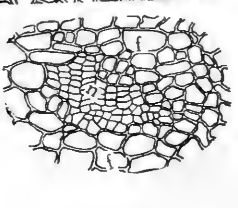

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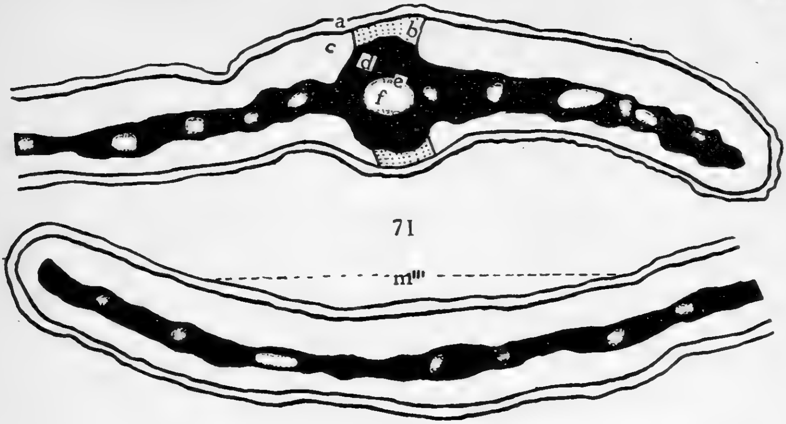

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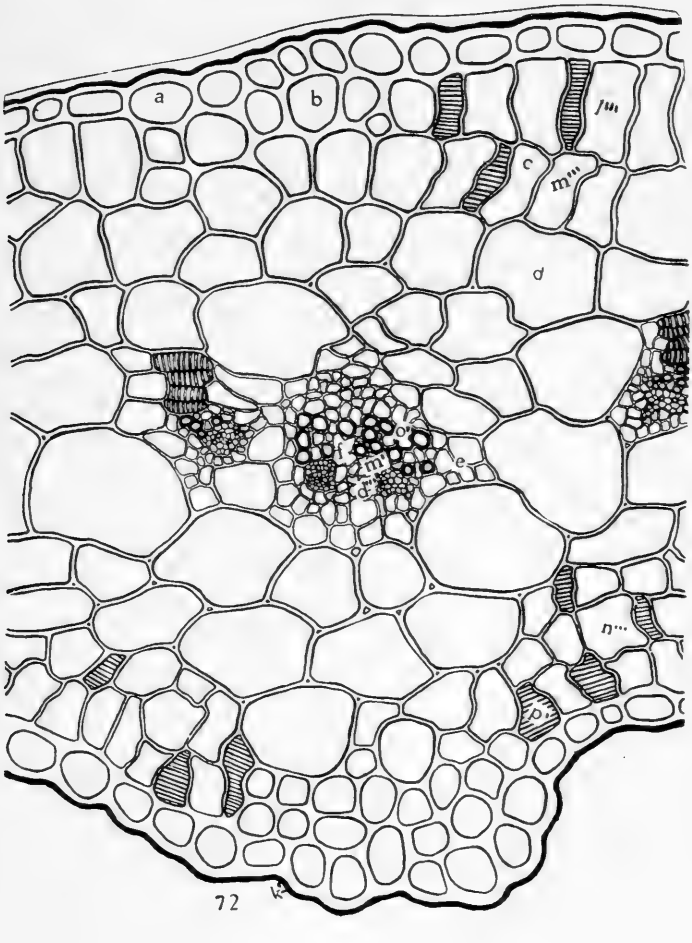

72

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PLATE XV.

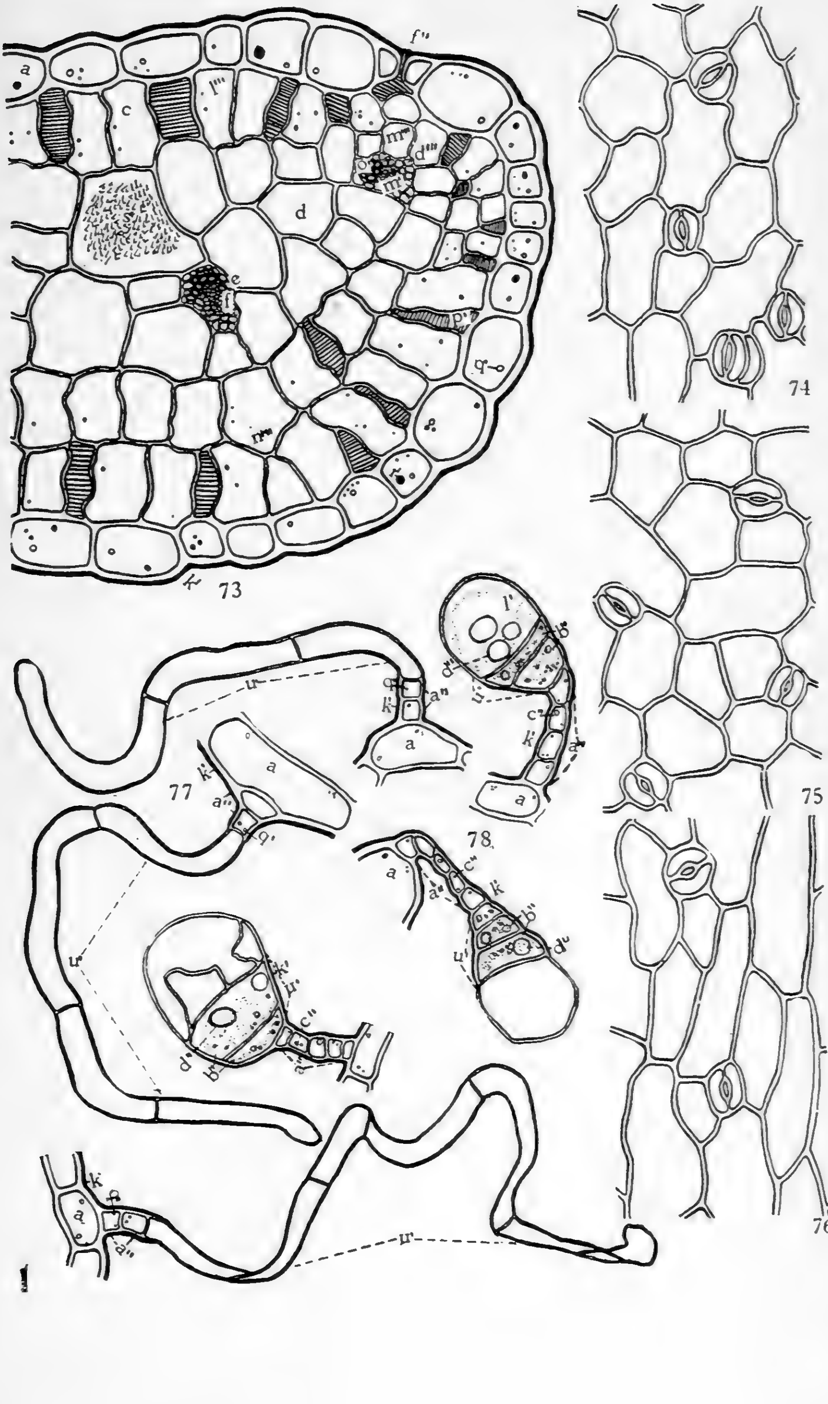

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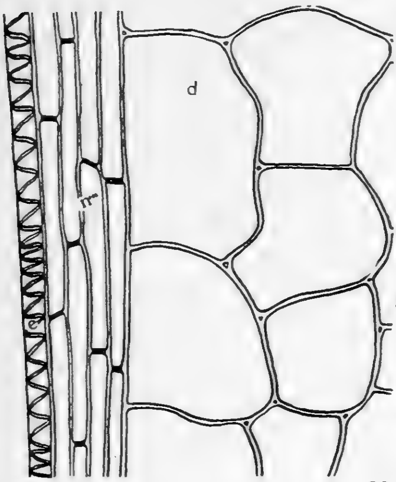
PLATE XVI.



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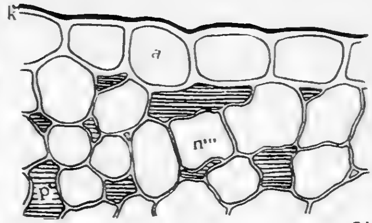

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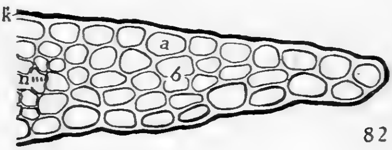

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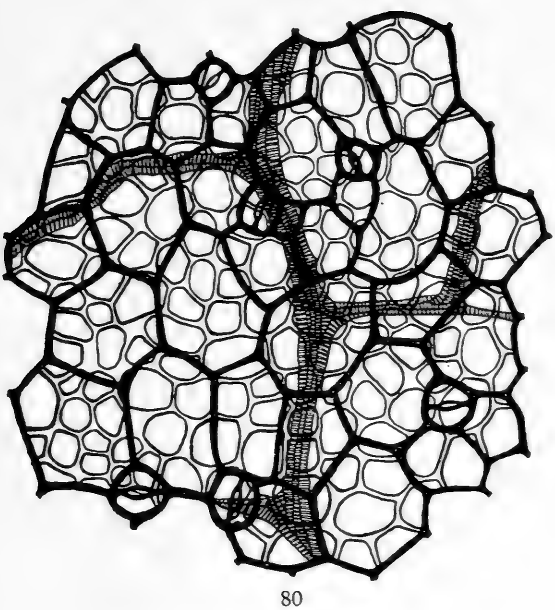

80

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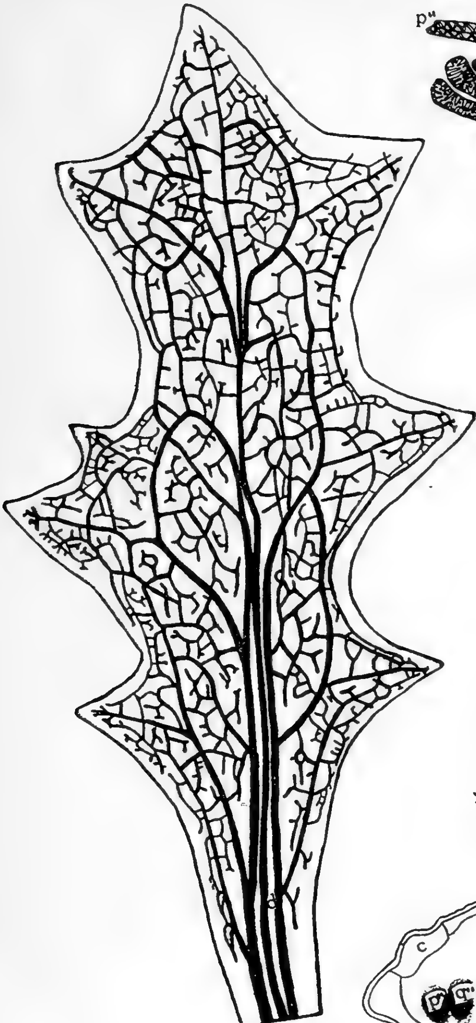
PLATE XVII.



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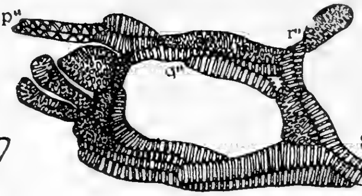

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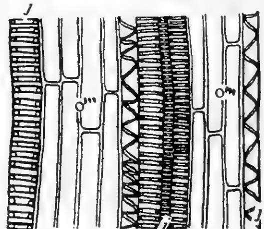

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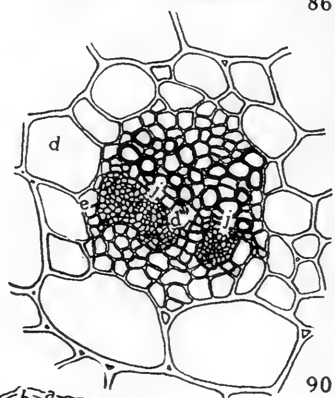

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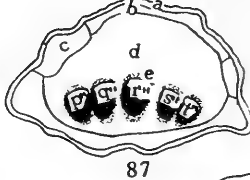

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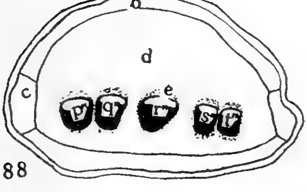

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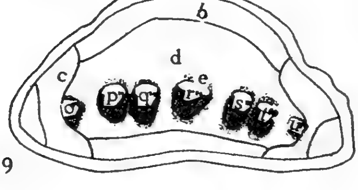

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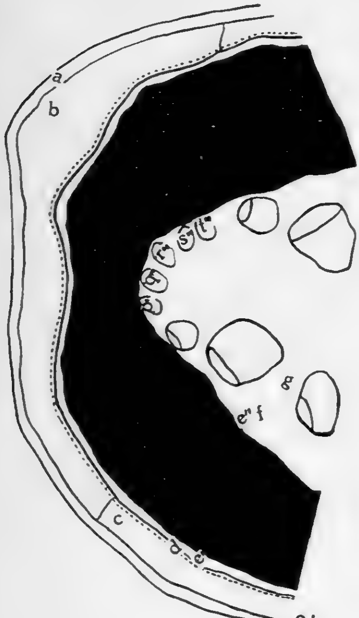

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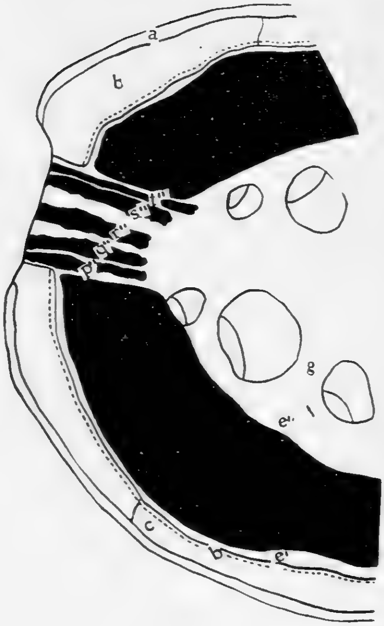

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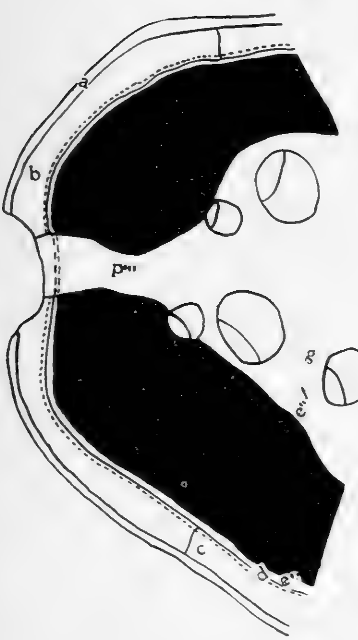

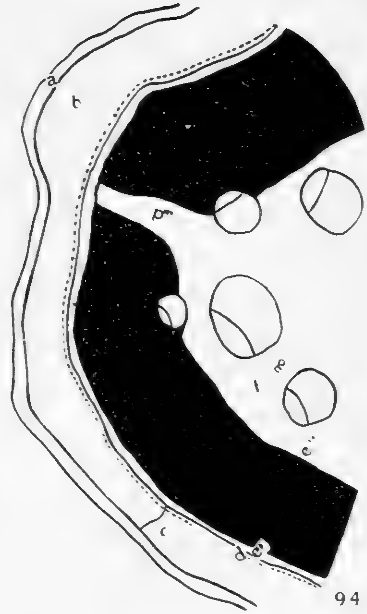

94

CYCLOLOMA ATRIPLICIFOLIUM.
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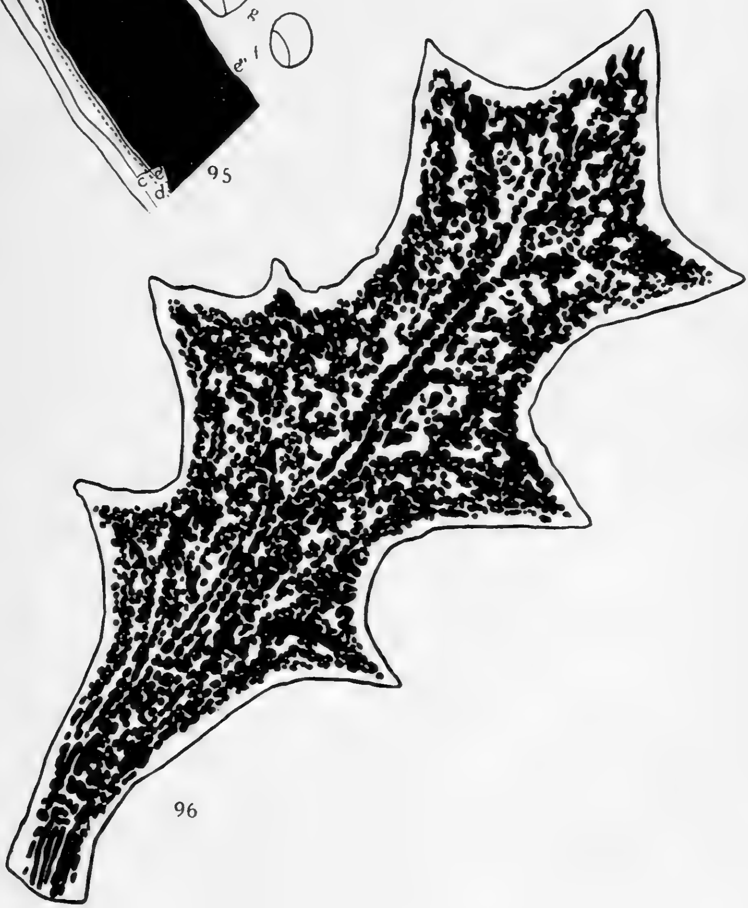
PLATE XIX.

95



96

THE

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CONTENTS:

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7-111

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Larval Trematodes from Kansas Fresh-water Snails.

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INTRODUCTION.

THIS study of larval trematodes was undertaken by the writer at the suggestion of Prof. Bennet M. Allen, in an attempt to add to the knowledge of this interesting group of parasites.

The snails used in the investigations were collected during the summer and fall of 1915 in connection with the Kansas State Biological Survey, and studies were made of the behavior and habits of the living cercariæ before the specimens were preserved for further morphological studies.

METHODS OF STUDY.

For convenience in transporting live snails, it was found desirable to tie the specimens in cheesecloth bags of twenty-five each, packing loosely in wet excelsior.

In the laboratory the snails were isolated in individual watch glasses and kept covered with water. Normally the cercariæ emerged within two or three days. Some of the infected snails were then preserved entire, and others were crushed for studies of living sporocysts and rediæ.

The fixatives used were a saturated corrosive sublimate solution with one per cent glacial acetic acid, Zenker's fluid, and four per cent formalin. The latter was discarded after trials proved the superiority of the other fixatives. Corrosive sublimate was preferable for free cercariæ.

Several different stains were used. Picrocarmine was excellent for studies of the living cercariæ. Specimens so stained could

sometimes be preserved by drawing glycerine under the cover slip with filter paper. For toto counts, Mayer's hæmalum gave the best results. The sections were cut from five to seven micra in thickness and stained with iron alum hæmatoxylin. Good results were also obtained by staining with hæmalum and using eosin or orange g. for counter stains.

The free cercariæ could be made to expand by heating slightly. When they were in this condition the fixing fluid was poured on suddenly, fixing the specimens in the best form for study.

The measurements given in this paper were taken usually from mounted specimens, and are not as accurate as those from living forms would be, because of shrinkage of the specimens during the process of fixing and mounting.

Amphistome Cercariæ.

Three species of amphistome cercariæ were found in my collections. For the first of these I propose the name *Cercaria cortii*.

Of twenty-three specimens of *Planorbis trivolvis* collected at Cherryvale, Kan., October 16, one was infected with *Cercaria cortii*. The snails were found adhering to rocks at a depth of from six inches to a foot in a large pond of clear water.

On October 17 the snails were isolated in individual watch glasses and kept covered with water, the water being changed each day. Cercariæ were noticed in one dish as follows, the observations being made in the morning at eight o'clock:

October 18	6 cercariæ.
October 19	12 cercariæ; all others encysted.
October 20	3 cercariæ; all other cercariæ encysted.
October 21	0 cercariæ; all other cercariæ encysted.
October 22	0 cercariæ; all other cercariæ encysted.
October 23	0 cercariæ; all other cercariæ encysted.
October 24	0 cercariæ; all other cercariæ encysted.
October 25	50 cercariæ; five encysted.
October 26	6 cercariæ; all others encysted.
November 2	All cysts still alive in water.
November 3	One new cercaria encysted.
November 4	One new cercaria encysting.
November 6	One new cercaria; all encysted.
November 5-7	No new developments.
November 8	Snail dead.

The cercariæ within the cysts were alive after having been kept in the water for twenty days, although only those that were opened within four days after they encysted, moved about.

One lot was allowed to dry for forty-eight hours, being kept in a covered watch glass. The air was moist, but there was no water covering the cysts. The cysts were covered with water and later opened. The cercariæ were alive and active. Longer and more complete desiccation proved fatal to the cercariæ.

The process of encysting was carefully noted for this species. The swimming ceases; the anterior end of the body is directed downwards or towards the side of the container; the oral sucker becomes attached; the tail vibrates rapidly, then the cercaria loosens its hold and goes through creeping motions, but does not swim any. This process is repeated a few times, then the cercaria flattens itself against the glass and assumes a spherical shape. The head is twisted from side to side within the cyst wall, and the tail continues to vibrate. The worm becomes more transparent and the cercaria seems to loosen from the outer wall, which assumes a furry appearance, due to the giving off of cystogenous material by the cystogenous glands. At this time, the cercaria begins peculiar rotating movements, which continue from an hour and twenty minutes to two hours and ten minutes. The motion consists of a series of intermittent movements. The time required for a cercaria to make a complete turn varied from one and three-fourths minutes to two and a half minutes, with from thirteen to twenty-two separate movements in a revolution.

The cyst wall becomes thicker and more transparent. Sometimes the tail loosens and swims away, while at other times it may remain loosely attached to the cyst. One tail vibrated constantly for eight hours after the cercaria began to encyst. The tail as well as the body gives off cystogenous material, which is in the form of a delicate sheath surrounding that organ and at a distance of one-half the width of the tail from it.

The motions of the encysting cercaria become slower and slower, and finally cease as the process is completed. When the cyst is fully formed it is much more transparent than the free-swimming cercaria, and the worm is coiled within the cyst with its anterior and posterior ends in contact. Slight spasmodic motions within the cysts can be noted for three or four days after encystment. Sometimes the cercaria breaks out of its cyst by rupturing the wall, and forms a new cyst. The cercariæ usually encysted on the bottom and sides of the watch glass nearest the window, and were shaped like a deep plano-convex lens. In a few cases where encystment took place among masses of snail fæces and

not against the side of the container, the shape of the cysts was ellipsoid.

Cercaria cortii is a rapid swimmer, and its swimming motions are strikingly regular. It would often propel itself in a straight line from one side to the other of a Syracuse watch glass. Creeping motions were rather infrequent in open water, but under the cover slip this was the usual method of locomotion.

The measurements of this cercaria were taken from preparations mounted in glycerine and glycerine jelly after the specimens were killed by heating slightly, and represent as accurately as possible the size of the form in life.

This cercaria is elongate, oval, and wider at the posterior than at the anterior end. It is capable of assuming shapes varying from spherical to long and narrow. The length of the body is .94 mm. and the length of the tail is .87 mm.; a total length of 1.81 mm. The width of the acetabulum is .25 mm. and the width of the oral sucker is .08 mm. The edge of the oral sucker presents a finely lobated appearance.

The mouth is situated within the oral sucker and opens into an oral cavity .01 mm. wide and .06 mm. long. This is separated from the esophagus by a constriction. The esophagus narrows into a pharynx about one-third the diameter of the oral cavity. It is surrounded by a band of longitudinal muscle fibers .027 mm. in outside diameter. The width of the digestive diverticula is .017 mm.

Fig. 2, a cross section through the region of the eyespots, shows the brain. The nerve cords could not be traced any distance from this region.

The anterior one-third of this cercaria is heavily pigmented with dark pigment.

The esophagus is long and narrow. The digestive tract extends five-sevenths of the length of the body. The two eyespots are prominent and are .028 mm. in diameter and .16 mm. apart. The tubes of the excretory system extend from near the eyes to just in front of the acetabulum.

The excretory tubes are made up of large flame cells, irregularly joined together, and very closely associated with the digestive tract. In the living form these tubes appear to be cylindrical and rather regular in shape, but cross sections of the fixed specimens (fig. 3) show the true nature of these ducts. In some places they seem to take a spiral course around the diverticula of the digestive tract. These cells contain concretions .007 mm. in diameter.

In the living form these concretions look like highly refractive cell nuclei and mark out the excretory tract very distinctly. The excretory vesicle into which the paired tubes open is just anterior to the acetabulum and is .017 mm. in diameter.

From the living specimen one would think that the tail contains an excretory canal, but cross sections show that the central region of the tail is made up of very large cells with extremely delicate walls. Encircling this central region is a cylinder of smaller cells and a narrow band of outer longitudinal muscle fibers.

The anlagen of the reproductive organs show as rounded masses of deeply staining cells, within the diverticula of the digestive tract. Cystogenous glands are present all over the body excepting in the immediate vicinity of the oral sucker and mouth. Within the cystogenous glands are granules of the cyst-forming material.

Of twenty-three specimens of *Planorbis trivolvis* collected at Lawrence, Kan., October 10, one was infected with *Cercaria diastrophora* Cort. The following additional description and accompanying plates may be considered merely supplemental to Cort's description of this form. These studies were made before the identification of the species had been established as being the same as *C. diastrophora* Cort.

In general appearance this form corresponds to *Cercaria cortii*, but it is much smaller, measuring .48 mm. long and .2 mm. wide. The tail is .58 mm. long. The oral sucker is small, measuring .06 mm. in width, while the acetabulum is exceedingly large, measuring .15 mm. in outside diameter.

The esophagus is very slender, opening into a bulbous pharynx three-fourths as broad as the tip of the oral sucker. The eyespots are prominent and are oval rather than spherical, measuring .027 mm. by .036 mm. They are separated by a distance equal to the long axis of the eye.

The excretory system consists of paired ducts opening into an excretory vesicle anterior to the acetabulum. This vesicle also receives smaller ducts from the region of the acetabulum. The excretory pore opens on the dorsal surface.

This species stains deeply with hæmalum, excepting in the region of the oral sucker, where the cells seem to be devoid of nuclei. The tail is made up of large central cells surrounded by a ring of smaller cells. It contains no excretory canals.

The immature cercariæ of this species are blunt-tailed and clumsy. No internal organs can be distinguished excepting the eyespots, which are rudimentary.

The rediæ of this form are short and blunt and are provided with anterior and posterior locomotor projections. The digestive tract is short and blunt. The cercariæ within the rediæ were all immature, due perhaps to the fact that the snail was not fixed until cercariæ had ceased to emerge from it. The rediæ average .88 mm. long and .25 mm. wide.

Of twenty specimens of *Planorbis trivolvis* collected at Lawrence, Kan., July 22, one was parasitized with *Cercaria inhabilis* Cort. These snails were obtained from the surface of Horseshoe lake, where they were attached to twigs and floating objects.

The cercariæ emerged from the snails that had been isolated in a watch glass, and remained in the immediate vicinity of the snail. Owing to their heavy tails and unwieldy bodies, their attempts at swimming resulted in their floundering about. The creeping motions also were very feeble. When the snail was crushed, rediæ and cercariæ in various stages of development were found in the liver. A remarkable fact in connection with this species was that the rediæ were smaller than the cercariæ.

This apparent inconsistency may be explained by comparing the free cercariæ with the sections of the infected snail liver, where free cercariæ are to be found completing their development in the digestive gland near the periphery of that organ.

The length of this species is .76 mm. and the width is .23 mm. There are two prominent pigment spots on the anterior dorsal surface of the body. The digestive tract consists of a slender pharynx leading from the mouth, situated within the oral sucker, to the diverticula of the intestine. The excretory system consists of paired tubes opening into the excretory pore just anterior to the ventral sucker. A mass of deeply staining cells, the anlage of the reproductive organs, is anterior to and below the pore.

The rediæ are elongated sacs, the immature ones averaging .55 mm. long and .07 mm. wide. The mature ones are slightly longer and twice as wide. The immature forms contain only germ balls, while the mature ones contain both germ balls and developing cercariæ that move about within the walls. No mature cercariæ were observed within the rediæ of this species.

Distome Cercariæ.

In my material are nine distome cercariæ, belonging to five subgroups.

MEGALUROUS CERCARIÆ.

Of twenty specimens of *Planorbis trivolvis* collected at Lawrence, Kan., July 27, one was infected with *Cercaria magnacauda*. This is an active free-swimming form, positively phototropic. It did not undergo creeping motions excepting when the tail was detached from the body.

The behavior of this cercaria was noted carefully. They would swim actively for a few minutes, then come to rest, pointing head downwards at an angle of fifteen degrees from the vertical. In this position the tail is blade shaped and flattened dorsoventrally. Practically all of the cercariæ would be either resting or swimming at any one time. These cercariæ were especially virile, living from thirty to forty-eight hours after emerging from the snail. The tail invariably became detached from the body and continued swimming after the death of the former. This form did not encyst.

The rediæ of this species were found in tangled masses in the liver of the host. They average .9 mm. long and from .1 mm. to .5 mm. wide, having a short digestive tract. The mouth is terminal and well defined, being provided with a large median stylet.

This remarkable cercaria has a total length of 1.56 mm., the body comprising only .127 mm. leaving it less than one-eleventh of the length of the tail. These measurements, which were taken from balsam mounts, are approximately normal, excepting that the tail is somewhat flattened.

From a study of the living material only the suckers and the concretions in the excretory ducts could be seen. Mounted specimens show the enormous excretory tract and the reproductive anlagen, while the cephalic glands can be seen in sections.

The excretory tract consists of two tubes extending from near the oral sucker to a large excretory bladder, posterior to the ventral sucker. This bladder communicates with another in the anterior narrow part of the tail. Opening into this secondary bladder is the median excretory duct of the tail, which is ventral in position.

The reproductive anlagen appear as two masses of cells anterior and posterior to the ventral sucker. No digestive tract could be traced.

The oral sucker is .007 mm. in outside diameter, while the ventral sucker is twice this size. The tail is made up of large parenchymous cells and longitudinal and cross-muscle fibers. Owing to its delicate structure it could not be embedded for sectioning.

ECHINOSTOME CERCARIÆ.

Of one hundred specimens of *Physa gyrina* collected at Lawrence, Kan., August 19, one was infected with *Cercaria fusiformis.* This species is characterized by a symmetrical spindle-shaped body with a long digestive tract extending from the oral sucker to near the caudal end of the body. While this species had all of the characteristics of the echinostome cercariæ, no spines are present anywhere. The region of the oral sucker presents a collared appearance. The total length of this cercaria is .77 mm. and the width is .07 mm. The oral sucker has an external diameter of .028 mm. and an internal diameter of one-fourth that size. The ventral sucker is about the same size and is capable of being greatly extended or projected. This form used the ventral sucker extensively in holding fast to the substratum.

The digestive diverticula do not inclose the ventral sucker as one would infer from the dorsal aspect, but are dorsal to it in lateral view. The digestive tract consists of a very narrow esophagus leading from the mouth to the pharynx. Just back of the pharynx is a median intestine extending as far as the anterior end of the ventral sucker, where it branches into two diverticula that extend back to the posterior end of the body. The esophagus measures .003 mm. wide and .03 mm. long. The width of the pharynx is .018 mm. and that of the intestine .012 mm.

The excretory tract consists of narrow paired tubes extending from the region of the pharynx to the posterior end of the body. The excretory bladder and the excretory duct, in the anterior part of the tail, could not be traced definitely, but appeared as more transparent areas in the toto mount.

The anlage of the reproductive organs is a dense mass of cells near the posterior end of the body.

The posterior sucker is very muscular. The figures accompanying the plate show this sucker open, closed, and extended.

The rediæ are large and contain from six to eight mature cercariæ, together with a few large germ balls. They are distended in places by the cercariæ contained within. The average measurements of the rediæ are, length 1.91 mm. and width .13 mm. to .33 mm.

GYMNOCEPHALOUS CERCARIÆ.

Of fifty specimens of *Physa integra* collected at Chanute, Kan., October 17, two were infected with *Cercaria gracilis.* I propose this name because of the ability of the species to draw itself out

into a very slender shape. The infection was slight, and these studies were made entirely from the living material and two mounted specimens.

This cercaria is exceedingly active and is capable of extending the body until it is as narrow as the tail. This form can also extend the ventral sucker until it appears prominent in a lateral view. In a characteristic position this form is slender, heart-shaped. The oral sucker is minute, the ventral sucker being four times as large.

The esophagus is slender and has a fold near the anterior end. Just beneath the fold is the narrow pharynx.

The diverticula of the digestive tract are broad, encircling the ventral sucker. The excretory system could not be made out, but paired rows of cells with highly *refractive* nuclei, or possibly concretions, mark this tract. The tail is broad and large, being one-third the width of the body and a little over twice the length of the same. The entire length of this cercaria is .53 mm.

The rediæ are of unusual shape, tapering at both ends with a definite collar near the anterior end. The digestive tract is slender, extending about half the length of the body. Within the rediæ are germ balls, developing cercariæ, and mature cercariæ. The dimensions of the rediæ are 1.6 mm. long and .33 mm. wide in the widest place.

FURCOCERCOUS CERCARIÆ.

Two per cent of large numbers of *Physa gyrina*, 436 in all, collected at Lawrence, Kan., during the months of July and August, from Haskell pond and the lake at Lakeview, were parasitized with a form for which I propose the name *Cercaria inversa*, because of its being directed tail foremost in swimming. The cercariæ emerged freely from the snails and flitted about rapidly in the water with a peculiar vibratile motion, directed tail foremost. Creeping movements were not observed excepting under the cover slip, when the tail became severed from the body. When the parasitized snails were crushed, rediæ containing cercariæ in all stages of development, from mere germ balls to mature forms, were present. The various stages in the development of the cercariæ could be easily observed because of the characteristics of the tails, which varied in length from mere stubs and rounded lobes to the elongate bifurcated tails of the mature forms.

The rediæ* were in a tangled mass in the liver. The largest

* Further studies showed that the rediæ of this species may be four times as long as the one shown in figure 47, and much constricted, resembling link sausage.

ones exhibited a slightly waving motion. Under the cover slip cercariæ emerged from the rediæ, usually tail first, from the birth pore near the anterior end. It required about two minutes for a cercaria to free itself from the redia. This form did not encyst, but the cercariæ soon died in the water, in no case living more than four hours after emerging from the snail. Those liberated when the snail was crushed lived only from eight to twelve minutes. The number of this species emerging from a single snail was estimated at five thousand.

Cercaria inversa is a small furcocercous form, corresponding as to size, shape and behavior to *Cercaria douthitti* described by Cort (1915), from *Lymnaea reflexa.* This species, however, contains no eyespots and is found in rediæ instead of sporocysts. The length of the body is .16 mm. in well-extended specimens, and the width is .045 mm. The unbranched part of the tail has a length of .26 mm. and a width of .027 mm., while the lobes are five-sixths as long as the main part of the tail and one-half as wide. These lobes taper to rather a sharp point. The openings in the suckers are about the same size, .01 mm., but the outside dimensions of the oral sucker are greater than those of the ventral sucker. The measurements are, oral sucker .042 mm. and ventral sucker .028 mm.

As in *Cercaria douthitti,* the region back of the center is filled with large cephalic glands. The ducts of these glands extend forward and open alongside the oral sucker (fig. 50). The excretory system of the body region could not be traced, but a duct extends through the main part of the tail and is joined by ducts from each branch. An excretory pore opens to the exterior between the forks of the tail.

The anlage of the reproductive organs is a mass of small cells near the posterior end of the body and ventral in position.

Six per cent of large numbers of *Physa gyrina* collected at Lakeview, Kan., August 20, were infected with a form for which I propose the name *Cercaria echinocauda.* Collections of snails from the same locality, made October 12, showed two per cent to be infected.

This cercaria was very active, swimming both forwards and backwards, but usually forwards, with a vibratile motion of the tail. The tail was loosely attached to the body and was easily severed. When this occurred the body died in about twenty minutes, while the tail lived for two hours, swimming about

actively. Six hours was the maximum time that these cercariæ remained alive after emerging from the snail.

The body of this species is .31 mm. long and .125 mm. wide. The main part of the tail has a length of .54 mm., while the branches are .18 mm. long. Two large eyespots are present. They are made up of minute pigment granules and measure .02 mm. by .014 mm. in dorsal view, being longer in the transverse direction.

An excretory tube begins in the branches of the tail and extends throughout the length of that organ to the excretory pore in the posterior end of the body. The excretory tract could not be made out in the body region.

The branches of the tail are provided with a sort of fin extending around the tip. This fin is beset with minute spines.

A mouth is present in the oral sucker, but there is no digestive tract leading from it.

The anlage of the reproductive organs is ventral in position and near the posterior end of the cercaria.

A peculiar characteristic of this species was that in the fixed specimen the tail is usually bent sharply at its junction with the body.

The rediæ of this species average .2 mm. long and .11 mm. wide. They are filled with germ balls and cercariæ in various stages of development. The anterior end is somewhat pointed, while the posterior end is rounded.

Cercaria echinocauda is similar to *Cercaria ocellata* La Valette St. George, as the measurements for this species fall within the wide range described for *Cercaria ocellata*. Both forms are provided with fin-like projections on the tail. The tail of *Cercaria echinocauda* is not very contractile, contrasting with that of *Cercaria ocellata*. The oral sucker of *Cercaria echinocauda* is also much larger than that of *Cercaria ocellata*. *Cercaria echinocauda* develops in rediæ, while *Cercaria ocellata* is found in sporocysts.

Of thirteen specimens of *Planorbis trivolvis* collected at Lawrence, Kan., October 7, two were infected with a cercaria for which I propose the name *Cercaria quieta*, because of its often remaining motionless, floating in the water for brief periods of time. Like *Cercaria inversa*, this cercaria has a bifurcated tail and swims by means of a rapid vibratile motion of this organ.

The tail is enormous in size compared to the body and is not constricted off from the body in the living specimen as is the case with other furcocercous forms. The tail of this species is never

severed from the body in the living form, and only rarely did it become lost during mounting.

The cercaria can swim either forwards or backwards. The tips of the bifurcated tail are fitted with adhesive organs by means of which they attach themselves to the substratum or other cercariæ. Both oral and ventral suckers are small and of uniform size, measuring .027 mm. in diameter.

The excretory system consists of paired ducts leading from the anterior end of the body to the junction of the body and tail, where they anastomose and extend on back to the excretory pore which opens between the forks of the tail. No excretory vesicle is present but the excretory tube is somewhat dilated just anterior to the excretory pore.

The anlage of the reproductive system is posterior to the ventral sucker. No digestive tract could be traced.

The total length of the cercaria is .8 mm. and the width is .08 mm., the main part of the tail being as wide as the body. Of the total length the body makes up one-fifth, the unbranched tail two-fifths, and the branched tail two-fifths.

The redia of this species is long and cylindrical, measuring 1.52 mm. by .2 mm. Each redia contains many cercariæ, about one-fifth of which are mature. The rediæ were so tangled in the liver that it was almost impossible to dissect them out entire.

XIPHIDIO CERCARIÆ.

My material contains three species of xiphidio cercariæ. Owing to the extreme difficulty of studying these small forms, my descriptions are in some places incomplete. I am unable to make these species fit in with previously described forms, much as they resemble forms described by Cort and Luhe.

For the first of these species I propose the name *Cercaria haskelli,* from the locality where it was found (Haskell pond). One of thirty-three specimens of *Physa gyrina* collected from this locality at Lawrence, Kan., July 12, was infected with this species.

Cercaria haskelli is a rapid swimmer, the swimming alternating with creeping movements. A marked characteristic of this species was that it could extend the tail until it was three or four times the length of the body. When this form was swimming, the body would be contracted into a ball and the tail would be very much extended.

The measurements for this species in an average state of contraction are, length .15 mm. and width .05 mm. The tail meas-

ures four-fifths the length of the body. A stylet protrudes from the region of the oral sucker. This stylet measures .037 mm. long and has a width at its base of one-fifth of the length. It tapers to a point and has no enlargements anywhere along its length.

The oral sucker is .04 mm. in diameter and the ventral sucker measures .03 mm. In longitudinal section, both suckers open into pouches wider than the external openings. There are two layers of cuboidal cells in the wall of the ventral sucker.

The muscular layers comprising the outer wall of the cercaria average .003 mm. in thickness.

The esophagus is exceedingly narrow, averaging .0015 mm. in diameter. It is grounded by a ring of deeply staining cells corresponding to the muscular pharynx seen in other forms. The esophagus broadens into a median digestive tract .03 mm. long and .0125 mm. wide.

Anterior to and dorsal to the ventral sucker are numerous unicellular glands. These are probably stylet glands, as their position is different from that of the cephalic glands described for *Cercaria inversa*, for instance. No ducts could be found leading from these glands.

The only excretory tract found consists of irregular spaces lying against the dorsal wall of the ventral sucker. In transverse section of the tail, four large central cells can be seen surrounded by a ring of muscle fibers. In some places the walls between these central cells are made up of smaller narrow cells.

The anlagen of the reproductive organs are in two masses dorsal to the ventral sucker. These masses are connected by a narrow band of similar cells.

Cercaria haskelli is found in sporocysts. They are rounded elongate sacs containing germ balls, developing cercariæ and mature cercariæ. The sporocysts are from .25 mm. to .42 mm. long and are from one-third to one-half as wide.

Of twenty-three specimens of *Planorbis trivolvis* collected at Cherryvale, Kan., October 16, five were infected with *Cercaria gregaria*. The cercariæ emerged from the snails by thousands and had the peculiar habit of massing together in the water. They would lose their tails and form such compact masses that they could not be separated without tearing the tissues apart. These masses contained from fifty to five hundred individuals each. The cercariæ remained alive in this condition for eight hours. No encystment was seen, and very few cercariæ remained for any length of time without joining with one of the masses.

This is an exceedingly minute form, measuring only .37 mm. long, including the tail, which is half the length of the body. The width is .03 mm. Both of the suckers are the same size, averaging .015 mm. in outside diameter. This form has a stylet .006 mm. long. On account of the minuteness of this form, the internal structures could not be made out clearly. The best results were obtained by staining intravitally with picrocarmine. With this stain paired masses of cephalic glands with their ducts could be made out. The tail of this form consists of large cells with a definite single row of nuclei, showing prominently in the median line.

Sectioning the snails from which these cercariæ emerged failed to reveal either sporocysts or rediæ.

Seventy-five per cent of hundreds of *Planorbis trivolvis* collected at Pratt, Kan., August 22, were infected with a small xiphidio cercaria which I propose to call *Cercaria kansiensis*. The body of this form averages .06 mm. wide and .09 mm. long. The tail in an average state of contraction is .064 mm. long.

The oral sucker is .024 mm. in diameter and the ventral sucker is .028 mm. The openings in both suckers are .007 mm. in diameter. There is a bicornuate groove in the posterior end of the body into which the tail fits.

No digestive tract could be traced, but a ring of deeply staining cells marks the region of the pharynx.

Large unicellular cephalic glands are present. They number about four on a side. No ducts could be found leading from them.

No excretory tubes could be found, but there is a large excretory bladder .01 mm. wide and .016 long, posterior to the ventral sucker. The long axis of this bladder is in a transverse direction to the long axis of the body.

The anlagen of the reproductive organs consist of two masses of cells dorsal to the ventral sucker. The posterior mass is the larger.

Special studies were made of the stylet of *Cercaria kansiensis*. It is embedded in the muscles of the thick-walled oral sucker, dorsal to the mouth opening, and can be withdrawn into a hollow receptacle. Two camera-lucida sketches (figs. 57 and 58) show the stylet extended and contracted. The stylet measures .02 mm. in length. At the base and near the point it has a width of one-sixth its length, but between these points it is narrower.

Cercaria kansiensis is found in sporocysts averaging .33 mm. long and about one-third as wide.

In all cases where this form was found, the infection was heavy, the liver of the snail being filled with almost a solid mass of the sporocysts. Estimates of the numbers of cercariæ emerging from any one snail ran from five thousand to eight thousand.

NOTES.

The following notes, while adding little to this paper, might be of assistance to any one wishing to work out life histories of trematodes.

The collecting grounds from which my material was taken covered a wide range of habitats, from temporary pools and pasture streams to artificial ponds and permanent lakes.

Only two genera of snails were examined. Infection was very rarely found in young snails, and never in snails collected from temporary pools or pasture streams. Old ponds harboring fish, frogs, muskrats and water snakes usually contained infected snails.

All of the furcocercous cercariæ were found in *Physa* collected from muddy permanent ponds. The large amphistome cercariæ and the xyphidio cercariæ were found in the genus *Planorbis* in the larger, clearer lakes. Lakes of this type are inhabited by the species of water life mentioned for the other type of ponds, and in addition are frequented by migratory birds.

The heaviest infection was found the latter part of August at the State Fish Hatchery at Pratt, Kan., where the number of snails parasitized ran as high as 90 per cent.

Only one of the species studied, *Cercaria cortii*, encysted under observation, and no cysts of any of the other forms were found outside of the snail.

One specimen of *Planorbis trivolvis*, collected from pond No. 5, July 24, showed the presence in the digestive gland of large numbers of spherical cysts about .05 mm. in diameter. These cysts correspond to those of *Cercaria trivolvis* described by Cort as having been found in the body cavity of *Planorbis trivolvis*.

One characteristic of *Cercaria gregaria* possibly throws some light on the life history of the species. This is the peculiar habit that the cercariæ have of losing their tails and forming compact masses in the water, each mass containing from fifty to five hundred individuals.

The following tables will be found useful for making summaries concerning the amount and kind of infection:

Pond Index.

No.	
1–Lawrence, Kan	Haskell, east of dairy barn.
2–Lawrence, Kan	Haskell, drainage ditch, south.
3–Lawrence, Kan	Stubbs' pond, northwest campus.
4–Lawrence, Kan	Stream, Woodland Park.
5–Lawrence Kan	Horseshoe Lake, six miles southeast.
6–Lawrence, Kan	Stream northwest of Griesa nursery.
7–Lakeview	East end of road through lake.
8–Lawrence Kan	Stream near E. A. Richards', six miles northwest.
9–Lawrence Kan	Stream one-half mile southwest of stream No. 8.
10–Lawrence, Kan	Bismarck Grove, North Lawrence.
11–Lawrence, Kan	Lake north of U. P. depot.
12–Lakeview	East of depot.
13–Pratt, Kan	State Fish Hatchery, Pond No. 22.
14–Pratt, Kan	State Fish Hatchery, Pond No. 39.
15–Pratt, Kan	State Fish Hatchery, Pond No. 41.
16–Pratt, Kan	State Fish Hatchery, Pond No. 51.
17–Pratt, Kan	State Fish Hatchery, Pond No. 77.
18–Pratt, Kan	State Fish Hatchery, Pond No. 1.
19–Lawrence, Kan	Railroad, one-half mile southeast of Haskell.
20–Lawrence, Kan	Pond on East Fifteenth street.
21–Baldwin, Kan	Pond in east edge of town.
22–Baldwin, Kan	Pond southwest of depot.
23–Baldwin, Kan	Pond center of town.
24–Ottawa, Kan	Stream east of Park, near library.
25–Ottawa, Kan	Pond near race track.
26–Ottawa, Kan	River west of west bridge.
27–Chanute, Kan	Santa Fe, one-half mile north of depot.
28–Chanute, Kan	Santa Fe, north of Frisco crossing.
29–Chanute, Kan	Santa Fe, two miles north, west side.
30–Cherryvale, Kan	Lake in city limits.
31–Cherryvale, Kan	Pond one-half mile north, along Santa Fe.
32–Abilene, Kan	Engle's pond, seven miles southwest.
33–Abilene, Kan	Pond one-half mile east of R.C. Lahr, southwest.
34–Abilene, Kan	Stream four and one-half miles southwest.

Percentage of Infected Snails.

Date.	Pond.	Host.	Number of snails.	Number infected.	Species.
7– 7	1	*Physa gyrina*	25	2	*C. inversa.*
7– 7	2	*Physa gyrina*	20	1	*C. haskelii.*
7– 9	1	*Physa gyrina*	95	0	———
7– 9	3	*Physa gyrina*	50	0	———
7–10	1	*Physa gyrina*	20	0	———
7–12	1	*Physa gyrina*	33	6	*C. inversa.*
7–20	1	*Physa gyrina*	130	0	———
7–21	4	*Physa gyrina*	23	0	———
7–22	1	*Physa gyrina*	30	1	*C. inversa.*
7–24	5	*Planorbis trivolvis*	15	1	*C. magnacauda.*
7–31	6	*Physa gyrina*	6	0	———
7–31	8	*Physa gyrina*	5	0	———
7–31	9	*Physa gyrina*	5	0	———
8– 2	7	*Physa gyrina*	10	1	*C. inversa.*
8– 3	7	*Physa gyrina*	12	2	*C. inversa.*
8– 4	8	*Physa gyrina*	20	0	———
8– 4	9	*Physa gyrina*	10	0	———
8–18	10	*Physa gyrina*	10	0	———
8–18	11	*Physa gyrina*	12	0	———
8–19	1	*Physa gyrina*	100	1	*C. fusiformis.*
8–20	12	*Physa gyrina*	100	6	*C. echinocauda.*
8–28	13	*Planorbis trivolvis*	16	4	*C. kansiensis.*
8–28	14	*Planorbis trivolvis*	30	13	*C. kansiensis.*
8–28	15	*Planorbis trivolvis*	20	3	*C. kansiensis.*
8–28	16	*Planorbis trivolvis*	20	16	*C. kansiensis.*
8–28	17	*Planorbis trivolvis*	20	16	*C. kansiensis.*
8–29	18	*Planorbis trivolvis*	29	13	*C. kansiensis.*
8–29	17	*Planorbis trivolvis*	25	21	*C. kansiensis.*
				2	*C. inversa.*
8–30	16	*Planorbis trivolvis*	50	45	*C. kansiensis.*
8–31	17	*Planorbis trivolvis*	50	34	*C. kansiensis.*
				2	*C. inhabilis.*
8–31	16	*Planorbis trivolvis*	90	75	*C. kansiensis.*
10– 7	12	*Physa gyrina*	50	1	*C. echinocauda.*
10– 7	5	*Planorbis trivolvis*	13	2	*C. inhabilis.*
10– 8	19	*Planorbis trivolvis*	12	2	*C. inhabilis.*
10–12	19	*Planorbis trivolvis*	23	1	*C. inhabilis.*
10–19	21	*Physa gyrina*	50	0	———
10–19	22	*Physa gyrina*	50	2	*C. haskelli.*
10–19	23	*Physa gyrina*	50	0	*C. haskelli.*
10–19	25	*Physa gyrina*	50	2	*C. haskelli.*
10–19	26	*Physa gyrina*	50	0	———
10–19	27	*Physa gyrina*	50	0	———
10–19	28	*Physa integra*	50	2	*C. gracilis.*
10–19	29	*Physa gyrina*	50	0	———
10–20	30	*Physa gyrina*	50	7	*C. gregaria.*
10–21	30	*Physa gyrina*	27	5	*C. cortii.*
11– 9	31	*Physa gyrina*	50	0	———
11– 9	32	*Physa gyrina*	100	0	———
11– 9	33	*Physa gyrina*	25	0	———

Favorable circumstances enabled the writer to continue his investigations of the cercariæ described in this paper during the summer and fall of 1916, and as late as January 5, 1917. The vicinities of Lawrence and Pratt were resurveyed, with the results that the species found the preceding year were verified by repeated collections and comparisons. *Cercaria magnacauda* was not found this season.

Many cases of double infection were found in *Physa gyrina* from pond No. 1. These cases of double infection were confined to two groups, one consisting of an infection of *Cercaria inversa* in rediæ in the digestive gland, and unidentified cysts in the body cavity,

corresponding in size to those of *Cercaria trivolvis* Cort. The other group consisted of a combination of the above-named cysts in the digestive gland, and a cluster of much larger cysts of a polystome cercaria on the periphery of the middle part of the snail inside of the shell.

Experimental work carried on with *Planorbis trivolvis* infected with *Cercaria kansiensis* at Pratt, during the summer of 1916, showed that cercariæ were continually emerging from snails kept in wire cages suspended in the ponds at the Fish Hatchery. These snails were taken from the cages each morning and confined in watch glasses in the laboratory. No characteristic swarming was noticed, but instead a few cercariæ could be seen emerging from the snails every time they were examined.

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EXPLANATION OF PLATES.

With the exception of Plate VII, all figures are drawn with the camera lucida. The abbreviations are after the plan adopted by Cort.

ABBREVIATIONS USED.

ac–acetabulum.
bp–birth pore of redia.
br–brain.
c–concretions.
cg–cystogenous glands.
ccg–cephalic glands.
dc–ducts of ccg.
e–eyespot.
es–esophagus.
ex–excretory system.
exp–excretory pore.
exd–excretory duct.
exv–excretory vessel.
gb–germ ball.
i–intestinal cæcum of cercaria.
ir–intestine of redia.
la–locomotor appendage of redia.
lc–large central cells of tail.
ml–muscle layer.
os–oral sucker.
p–pigmentation.
pb–pharyngeal bulb.
pr–pharynx of redia.
ra–reproductive anlage.
s–stylet.
sr–stylet of redia.
sc–cercariæ in sporocysts.
sg–stylet glands.
sw–wall of sporocyst.
vs–ventral sucker.

PLATE I.

FIG. 1. *Cercaria cortii.* × 61.
FIG. 2. Cross section of *C. cortii* through brain. × 122.
FIG. 3. Cross section of *C. cortii* through reproductive anlage. × 122.
FIG. 4. Cross section of tail of *C. cortii.* × 244.
FIG. 5. Longitudinal section of tail of *C. cortii.* × 244.
FIG. 6. Cyst of *C. cortii,* dorsal view. × 61.
FIG. 7. Cyst of *C. cortii,* lateral view. × 61.

PLATE II.

FIG. 8. *Cercaria diastrophora* Cort. × 144.
FIG. 9. Cross section of *C. diastrophora* through oral cavity. × 288.
FIG. 10. Cross section of *C. diastrophora* through pharynx. × 144.
FIG. 11. Cross section of *C. diastrophora* through reproductive anlage. × 144.
FIG. 12. Cross section of tail of *C. diastrophora.* × 288.
FIG. 13. Immature redia of *C. diastrophora.* × 144.
FIG. 14. Mature redia of *C. diastrophora.* × 72.
FIG. 15. Longitudinal section through excretory pore of *C. diastrophora.* × 576.

PLATE III.

FIG. 16. *Cercaria inhabilis* Cort, dorsal view. × 44.
FIG. 17. Immature *Cercaria inhabilis.* × 36.
FIG. 18. Immature redia of *C. inhabilis.* × 36.
FIG. 19. Mature redia of *C. inhabilis.* × 36.
FIG. 20. Cross section of *C. inhabilis* through intestinal cæca. × 160.
FIG. 21. Cross section of *C. inhabilis* through excretory pore. × 160.
FIG. 22. Cross section of tail of *C. inhabilis* near body. × 160.
FIG. 23. Cross section of tail of *C. inhabilis* near posterior end. × 160.
FIG. 24. *Cercaria gracilis.* × 160.
FIG. 25. Redia of *Cercaria gracilis.* × 36.

PLATE IV.

FIG. 26. *Cercaria fusiformis*, dorsal view. × 72.
FIG. 27. *C. fusiformis*, ventral sucker closed. × 160.
FIG. 28. *C. fusiformis*, ventral sucker open. × 160.
FIG. 29. *C. fusiformis*, ventral sucker lateral view. × 160.
FIG. 30. *Cercaria magnacauda*. × 72.
FIG. 31. Body of *C. magnacauda*. × 260.
FIG. 32. *Cercaria quieta*. × 72.
FIG. 33. Ventral sucker of *C. quieta*. × 260.
FIG. 34. Mouth of redia of *C. magnacauda*, longitudinal section. × 260.
FIG. 35. Mouth of redia of *C. magnacauda*, cross section. × 260.
FIG. 36. Redia of *C. fusiformis*. × 30.
FIG. 37. Redia of *C. quieta*. × 36.
FIG. 38. Redia of *C. magnacauda*. × 104.

PLATE V.

FIG. 39. *Cercaria echinocauda*. × 72.
FIG. 40. *Cercaria echinocauda*. × 72.
FIG. 41. Redia of *C. echinocauda*. × 36.
FIG. 42. Longitudinal section through *C. echinocauda*. × 160.
FIG. 43. Cross section through *C. echinocauda*. × 160.
FIG. 44. Tail of *C. echinocauda*, longitudinal section. × 160.
FIG. 45. Tail of *C. echinocauda*, cross section. × 160.
FIG. 46. *Cercaria inversa*. × 72.
FIG. 47. Redia of *C. inversa*. × 72.
FIG. 48. Cross section of tail of *C. inversa*. × 144.
FIG. 49. Cross section through cephalic glands, *C. inversa*. × 144.
FIG. 50. Cross section through oral sucker, *C. inversa*. × 520.
FIG. 51. Longitudinal section through excretory pore, *C. inversa*. × 260.

PLATE VI.

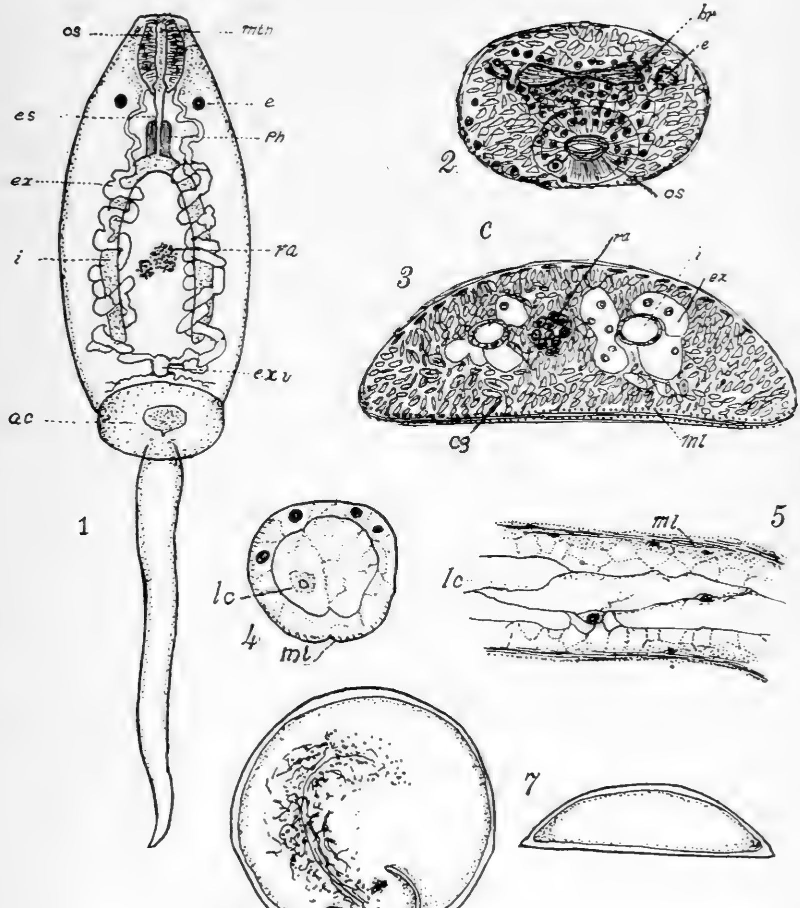
FIG. 52. *Cercaria haskelli*, dorsal view. × 144.
FIG. 53. *C. haskelli*, longitudinal section. × 160.
FIG. 54. *C. haskelli*, cross section through tail. × 160.
FIG. 55. Sporocysts of *C. haskelli*. × 72.
FIG. 56. *Cercaria kansiensis*. × 260.
FIG. 57. Lateral view of stylet, *C. kansiensis* withdrawn. × 260.
FIG. 58. Lateral view of stylet extended, *C. kansiensis*. × 260.
FIG. 59. Sporocyst of *C. kansiensis*. × 72.
FIG. 60. *Cercaria gregaria*. × 144.
FIG. 61. Longitudinal section of snail liver infected with *C. kansiensis*. × 44.
FIG. 62. Sporocyst *C. kansiensis*, cross section. × 260.

PLATE VII.

Reconstructions of the cercariæ described in the preceding pages all drawn to scale × 36. The numbers refer to the indices accompanying plates I-VI. Numbers 8′ to 56′ refer to sporocysts and rediæ corresponding to the cercariæ.

LARVAL TREMATODES.
E. C. O'Roke.

PLATE I.



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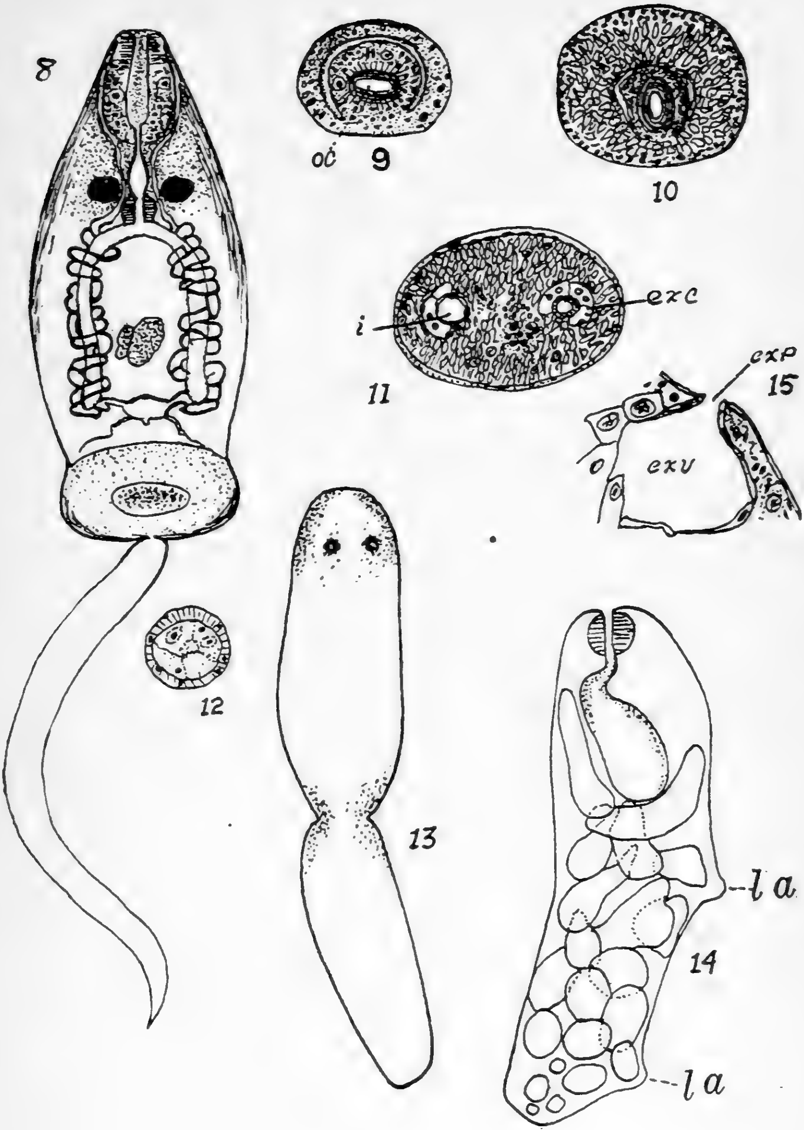

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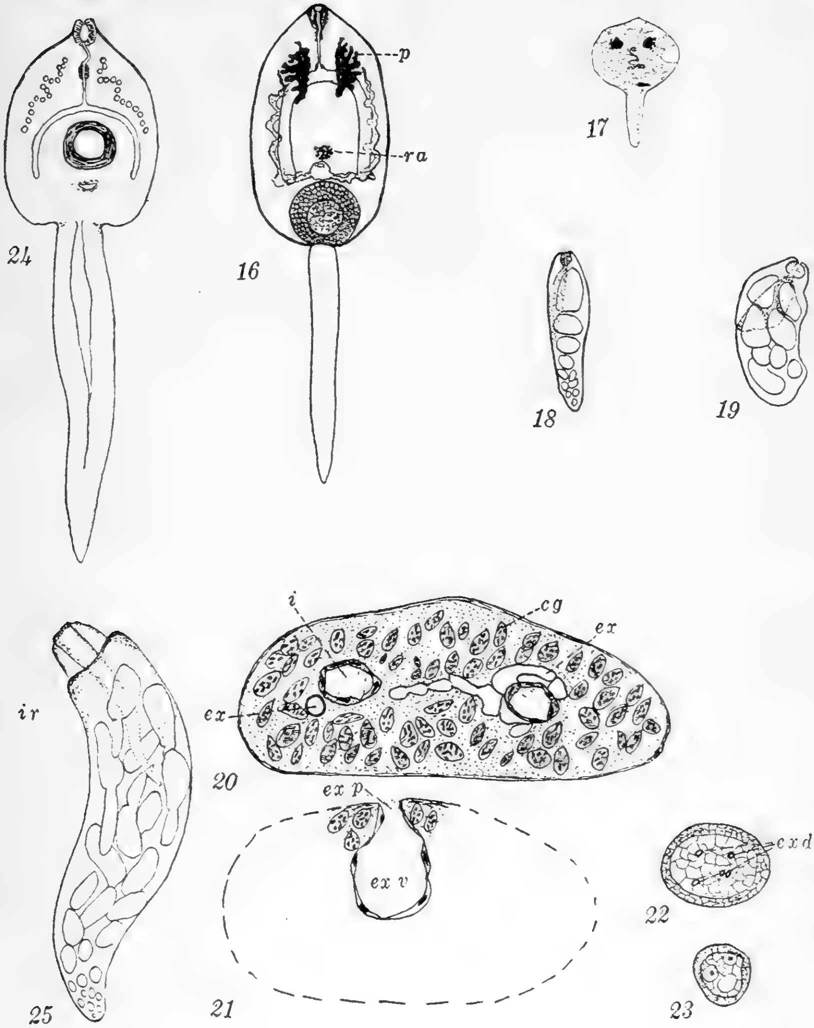

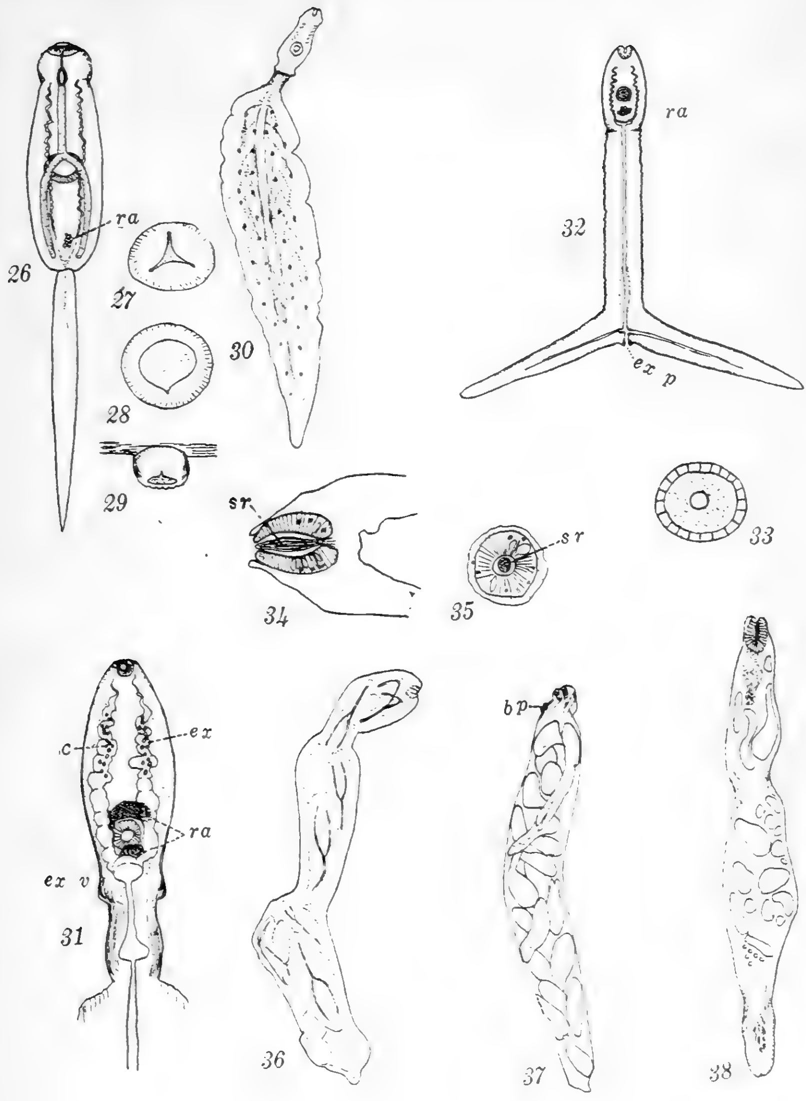
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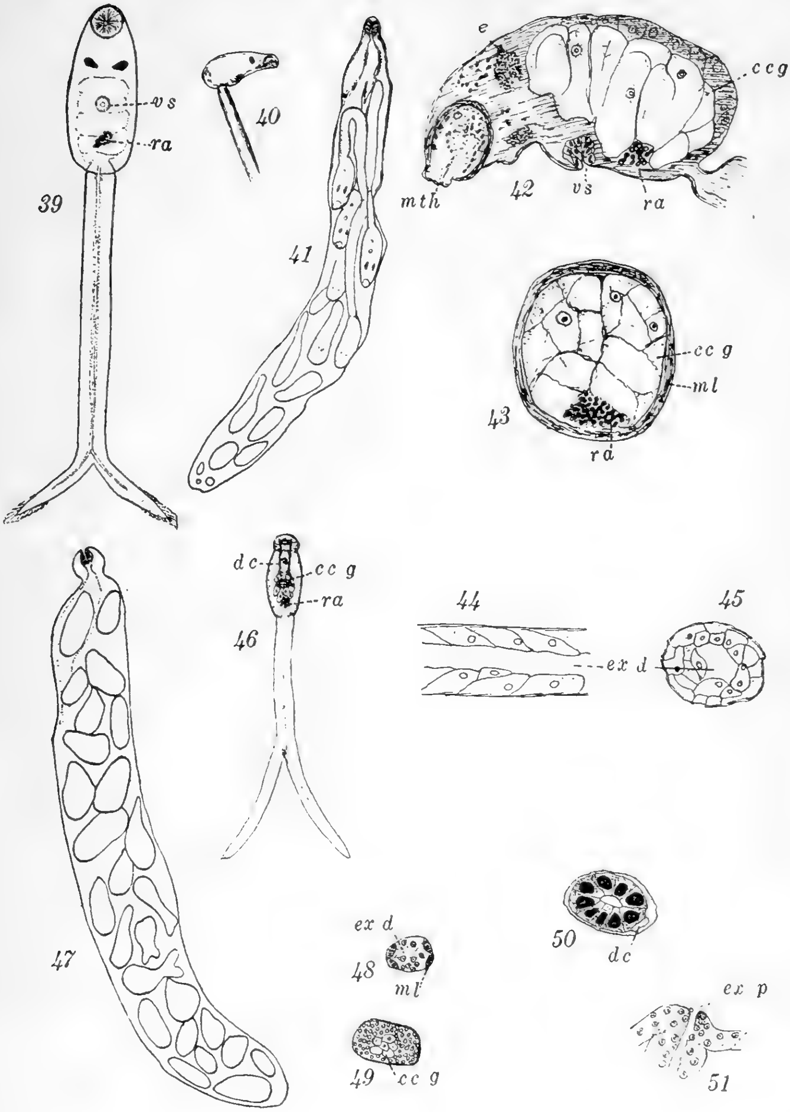
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PLATE VI.

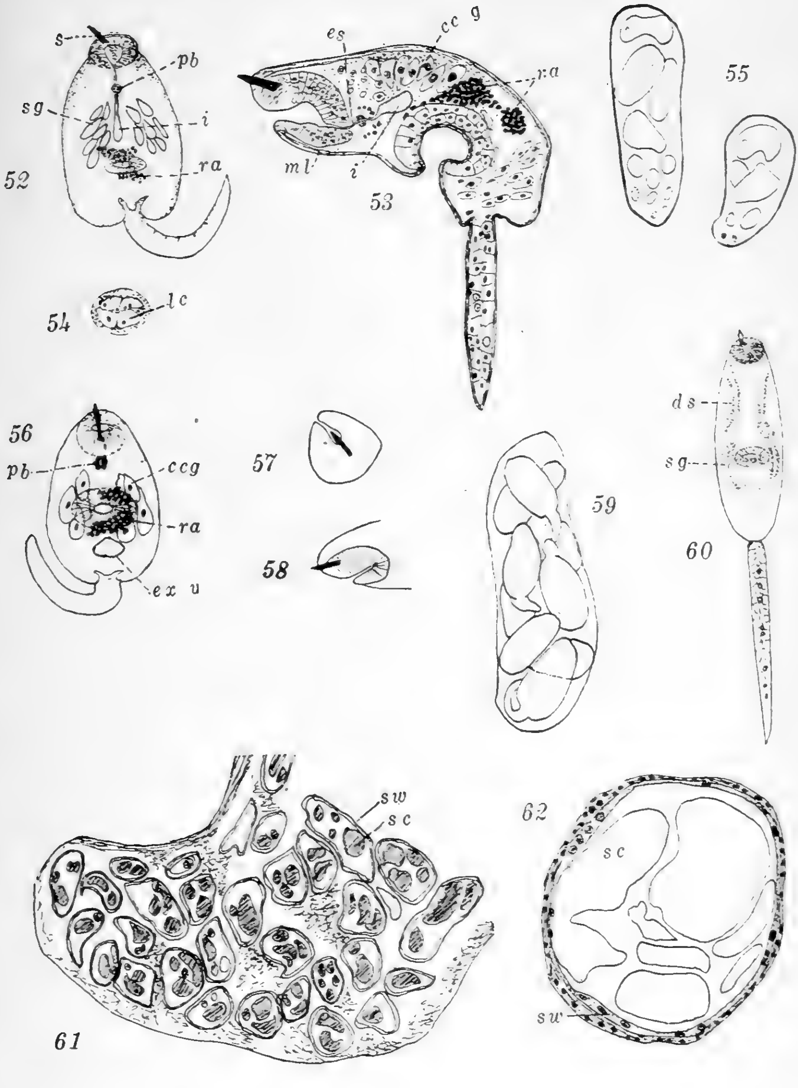
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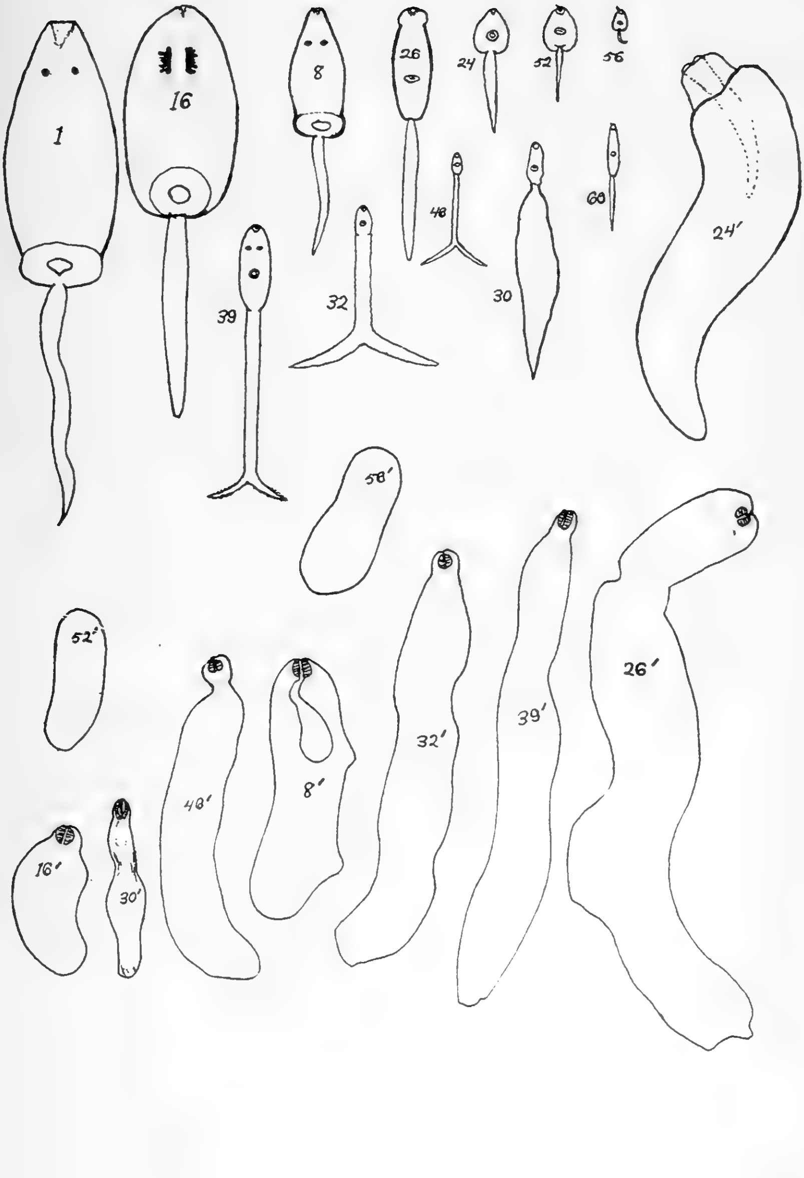
PLATE VII.



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Histology of *Astragalus mollissimus*.

BY NEVA RITTER.

"LOCO" in Spanish may be translated "crazy." The stock on the range in the western part of America were, therefore, said to be "locoed" when they exhibited symptoms of a disease involving loss of muscular control.

The first published account of the loco-weed disease was in the Report of the Commissioner of Agriculture for October, 1873, by Doctor Vasey. He attributed it to Astragali in California.

From then on every year appeared some new article, more of which were descriptions of the loco weeds and their effects on the stock than reports of discoveries of the true cause of the disease.

Professor Sayre ('86), of the University of Kansas, published articles in the Transactions of the Kansas Academy of Science and in the Report of the State Board of Agriculture describing the loco weeds in Kansas and telling of their effects on stock. He reported two loco weeds here, *Astragalus* and *Oxytropis* (*Aragallus*). He suggested the theory that the hairs on the leaves may by irritation cause the disease. In 1888 he reported having used the extract on himself and getting no resulting loco symptoms. In 1890 he separated some crystals which he said were inorganic and were not the poisonous principle. In 1892 he reported traces of alkaloid and said that loco weeds are not the cause of the disease of the stock. In 1898 he thought a poison develops in the animal which does not exist as such in the plant. In 1904 he put forth three possibilities of the cause of the disease:

(1) Irritation by hairs.
(2) Disturbance to digestion by eating much loco weed in the early spring.
(3) A poison develops during digestion.

Kennedy ('88) found no alkaloid nor poisonous principle when he used infusions in boiling water, dried powder, and an organic

acid from the plant. He experimented on a dog and came to the conclusion that the loco disease is due to the indigestible character of the plant.

Dr. Mary G. Day ('89) made a chemical analysis of loco weed. She experimented on a cat and rabbits. Her conclusions were that there is a poison in loco weed which will cause illness and death, and may be experimentally given and the same results obtained in cats and rabbits; and that the poison must be weak, or if strong, present in a very small amount.

Professor Mayo ('93) gave a good account of the symptoms. He said there is no evidence of a narcotic; the effect is due to malnutrition and malassimilation.

Ruedi ('95) experimented on sheep. In his chemical study he separated "locoin," a base, which he considered harmless, and an acid which is harmful.

Crawford ('08) claimed that barium in loco weeds is the poisonous principle, and tried to support his theory by numerous experiments on sheep and rabbits.

Marsh ('09) told of experiments on feeding and attempts at cure. He said advanced cases are hopeless; they may recover if taken early and put on good feed away from loco weed. He added that injections of sodium cacodylate or strychnine, or the two together for cattle, or Fowler's solution for horses, have been known to help. In 1912 he tried antidotes suggested by Crawford with no success.

Alsberg and Black ('12) tried to substantiate Crawford's contentions for barium, but failed to do so.

The loco disease in Kansas is nearly all due to *Astragalus mollissimus,* the purple loco weed. *Oxytropis* or *Aragallus lamberti,* the white loco or rattle weed, is more plentiful farther west. Of these the stock eat the *Aragallus* more readily, but the *Astragalus* is much the more poisonous. Other species of *Astragalus* and *Aragallus* have been found to be poisonous, but these two only are widespread enough to be of great economic importance.

Astragalus mollissimus of Kansas prairies has a short stem with long pinnately compound leaves, all very hairy, so that they appear silvery. The leaflets vary in number from few to thirty-seven or more. The root goes down quite deep. The flowers are purple, arranged on a spike, blooming the last of May and the first of June. These plants are perennial and remain green all winter. They grow in clumps scattered over the pastures, and are not uniformly distributed. They have many enemies, those

observed last summer being larvæ in the stem, insect galls, fungous diseases, and leaf miners.

Some of the theories proposed to account for the loco disease in stock caused by these plants are:

(1) The weed absorbs the juices of the alimentary tract, causes it to dry up and exert pressure enough to kill the animals.
(2) Overfeeding on loco weeds.
(3) A fungous parasite on loco weeds, Claviceps.
(4) The indigestible character of the plant.
(5) Malnutrition and malassimilation.
(6) Starvation.
(7) Irritation by hairs.
(8) Disturbance to digestion.
(9) Poison developed in digestion.
(10) Not due to loco weeds, but accompanying them.
(11) Alkaloids.
(12) Some poisonous principle not yet isolated.
(13) Barium salts.

The effects of the disease on animals have been described as various. However all agree on a few, as here given by Marsh ('09).

Slow staggering gait.
Rough coat.
Staring look.
Emaciation.
Lack of muscular coördination.
Extreme nervousness, shown in shying, rearing, etc.

To which might be added:

Lack of sensitiveness.
Hallucination.

A horse walking under a telephone wire several feet above its head will lower its head to get under, or when stepping over a stick or a rut in the road will lift its feet very high. The coat of the animal becomes rough, the eyes have a glassy look; there may be, in cattle, a sac of serous fluid under the chin. After the habit of eating loco weeds is formed the animals will hunt for them, and reject other food in preference to them. When locoed they are very hard to manage, and it is almost impossible to back a locoed horse. One cow is reported, when shut up to keep her away from the loco weed after she had the habit, to have run against a stone wall so hard as to kill herself. Starting to walk across a pasture, affected animals keep going until they come against some obstruction. A horse will walk through a barb-wire fence, not

noticing the cuts at all. They finally forget to drink even, and slowly starve to death, hunting loco weeds all the time, and eating nothing else.

If taken from the loco weeds at first they may be cured by shutting them up and feeding, but after the habit has become firmly fixed they are incurable. Prophylaxis is to rid the pasture of loco weeds, but this is practical only in small fenced lots. If fed plenty, so they need no more, in the winter, the habit is not nearly so readily acquired. Loco weeds are usually first eaten in late winter or early spring when the grass is dried up and these plants are still green.

One suggested possibility is that an alkaloid is the cause of the toxicity. Some analyses have shown it, others not. Dean Sayre has found a trace of alkaloid, but as much or more in alfalfa. Miss Watson ('78) found an alkaloidal reaction in the root, also a resinous body. Power and Cambier ('91) found toxic alkaloids, together with volatile oil, acetic acid, resin, albuminoid, and globulin.

Crawford ('08), while working to find the cause of loco poisoning, discovered a trace of barium, which was verified by spectroscopic examination. He measured .01 per cent barium oxide in the ash, which indicated 1.56 milligrams of barium sulphate in 1 gram of ash. In some of the soils in that vicinity he found, by similar examination, no trace of barium, nor in the well water. His experimental results show that barium in the proper amounts, as well as loco weeds, will kill animals; so his conclusion is that barium in loco weeds causes their toxicity. He removed barium with sulphuric acid and found the solution harmless. His extract of the dried material was not always active, which fact he thinks means that there is something in the fresh plant which aids the solution of the barium. His theoretical antidote is sulphuric acid.

Working on this basis, Marsh ('12) experimented with three lots of cattle. One lot were under normal pasture conditions; one was given drinking water containing the amount of sulphuric acid calculated to neutralize the amount of barium eaten in loco weed; the other lot was given drinking water containing a like amount of magnesium sulphate. The same proportion of each lot became locoed, thus showing that neither sulphuric acid nor magnesium sulphate are antidotes, as they should be if barium is the cause of the toxicity, so he makes the statement that barium is not the poison.

A laboratory investigation by Alsberg and Black ('12) on the barium question shows that barium is not responsible for the toxicity of loco weeds. Their evidence is: Many plants which are harmless contain as much or more barium than loco weeds; there are enough other metals present to explain the action attributed to barium; extracts of alfalfa, which are prepared similarly to extracts of loco weed which are toxic to laboratory animals, are found to be toxic to some laboratory animals; the barium is present in "at most but minute traces."

ORIGINAL INVESTIGATION.

ALKALOID. The alkaloid test is a reddish-brown precipitate with bromine or iodine. When the bromine reagent is applied to sections of the petiole, leaflet or stem, and a control (soaked in alcoholic tartaric acid for two days, then in water one day), no difference can be seen in the sections. The same is true when potassium iodide-iodine is used as an indicator. Both of these tests were repeated many times on all parts of the freshly picked plant, indicating no alkaloids.

As a control to the test for alkaloids, sections of nux vomica seeds, calabar beans and belladonna root were soaked in the solvent for alkaloids. These and fresh sections were tested for alkaloids at the same time with potassium iodide-iodine. A very noticeable difference was discernible. The fresh sections show a deep orange-brown color; the alkaloid-free sections a light yellow color, if any. So if an alkaloid were present in my loco weed, a difference in color between fresh and control sections should have been detected; but as there was none, the conclusion reached is that there is no alkaloid present.

SUGAR. Sugar is present in a fairly large amount. When sections of the leaf or stem are boiled in Fehling's solution, at first there is no change, but after boiling longer the brick-red precipitate appears, indicating that cane sugar or a glucoside is probably present. This is indicated in all the cells except the bast fibers and water tubes. Loco weed gathered at 9:30 at night showed the presence of a quantity of sugar in the green parts on boiling with Fehling's solution; that gathered early in the morning not so much.

STARCH. Starch is present in great quantities in the stem, in the pith, medullary rays, pericycle and cortex. In the petiole the starch sheath contains it abundantly, but there is little in the pith.

In the leaflet the palisade cells are full of starch grains. These grains are definite in shape and about three microns in diameter. Potassium iodide-iodine and chloroiodide of zinc are the indicators used.

Material gathered early in the morning showed much starch in the stem, but less in the green parts; that gathered at night showed an abundance in the green parts.

PROTEIN. When Millon's reagent is applied to sections they immediately begin to turn pink, which color deepens on standing or on heating. Protein is thus found to be present in the pith, medullary rays, pericycle, cortex, and especially much in the food-conducting tissues of the stem. In the petiole the same is true except that the pith contains very little. It is uniformly present in the leaflet. Potassium iodide-iodine confirms these indications. Material collected in the early morning and at night seems to contain the same amount.

MUCILAGE. Mucilage is present in the stem, as shown by methylene blue. Sections soaked in water still give the mucilage reaction, showing that it is not completely soluble in water, but might swell. A section of petiole was taken, mounted in alcohol, a distance measured, then water applied at one side of the cover glass. The cells immediately began to swell, the measured portion, sixty microns, swelling to seventy-five microns in a few minutes. The cells could be seen to round out. The mucilage was found to be more abundant near the edge of the section than in farther. The leaflet shows mucilage also. This occurrence of mucilage is interesting, as it is from species of *Astragalus* that the gum tragacanth of commerce is obtained.

OIL. Sudan III shows minute droplets of oil, in the pith cells especially. Sections soaked in ether overnight show less of this. Pieces of stem and leaf were steamed, the stem being collected on cover slips. These were first thoroughly cleaned with ether and handled with forceps. After staining with Sudan III no drops of oil are seen; therefore I conclude no volatile oils are present.

TANNIN. Tannin is indicated by a purple color appearing when ferric chloride is added to sections containing it. No indication of it could be discovered in stem, petiole or leaflet. The test was repeated several times, always on fresh material.

RESIN. Sections were soaked in a saturated aqueous solution of copper acetate, which turns resin green. Observations taken

occasionally for several months show no indications of the presence of resin.

OXIDASES. Gum guiac solution will not turn blue except when oxidases are present. It does not turn blue with any part of loco weed, meaning there are no oxidases present. When hydrogen peroxide is added a dark-red color appears, instead of the deeper blue, which is usual for peroxidases. This may mean a peroxidase is present together with some modifying substance.

GLUCOSIDES. Sections of loco weed treated in the following ways were boiled with Fehling's solution a few minutes, then observations taken:

(1) Fresh sections, no crystals.
(2) Treated with potassium hydroxide overnight at room temperature, cuprous oxide crystals present.
(3) Treated with hydrochloric acid overnight at room temperature, cuprous oxide crystals present.
(4) Treated with sulphuric acid overnight at room temperature, cuprous oxide crystals present.
(5) Treated with alcohol overnight at room temperature, cuprous oxide crystals present.

Untreated sections show crystals on long boiling with Fehling's solution. The same results were obtained when the treated sections were sealed with Fehling's solution and left in a warm place a few days. Sections of material preserved in formalin and treated in the same way give the same results.

These experiments may mean that glucosides are present which are broken by the various reagents used, giving the test by means of the freed sugar.

Crawford says that when sulphuric acid is added to an aqueous solution of harmful loco weed, it is rendered harmless because the barium is taken out of solution and made into barium sulphate. A section of loco weed was sealed with Fehling's solution and kept in a warm place. One week later crystals of cuprous oxide were noticed, showing that no glucose was present at first, or the crystals would have appeared sooner. It was probably a glucoside broken up by long standing and heating in Fehling's solution. Sections were soaked overnight in dilute sulphuric acid at room temperature. The next morning they were sealed with Fehling's solution. After five hours they contained many crystals of cuprous oxide. What happened in a week with Fehling's solution took place in a small fraction of that time with sulphuric acid. I think the change in toxicity in the solution which Crawford used was

due to the glucoside being broken up and thus being rendered harmless, instead of the barium being taken out of solution.

Crawford also states that in dried plants found by him to be inactive the barium has been converted into an insoluble form by drying. Sections of dried plants give a sugar test more readily than formalin or fresh material. This may be due to the glucoside being broken up in the process of drying. Crawford found aqueous extracts of the dried material ineffective, but experiments by others with feeding the dried material show it to be as toxic as fresh. This glucoside is soluble in water, as water in which sections have been soaked for some time show cuprous oxide crystals on heating with Fehling's solution, and the extracted sections have very few crystals in them.

From the experimental data at hand my conclusions are: That the toxicity of loco weeds may be due to some glucoside which is present, but which may be broken apart by various reagents; that the reactions which Crawford ascribed to barium are really due to this glucoside, the presence or absence of which can be proved more readily than the toxicity of such minute quantities of barium as he says are present in the plant.

ANATOMY.

THE LEAF. The leaf is compound, of few to thirty-seven or more leaflets. These as well as the petiole are densely covered by long unbranched hairs. (Figs. 1 and 2.) These occur equally on both sides of the leaf, about fifty per square millimeter. Their occurrence is shown in fig. 3. These hairs are composed of three cells, the basal cell, above this a very short cell with dense protoplasmic contents, and a very long terminal cell with thick cellulose walls. This terminal cell has no cutinized surface, as demonstrated by chloroiodide of zinc, Sudan III, or safranin-hæmatoxylin. There are small irregularities on the surface of this cell of the hair.

These terminal cells of the hair contain no living protoplasm. Methylene blue penetrates the cell wall, but does not color any contents. Hæmatoxylin stains the walls light violet, showing they are cellulose, but stains no contents, the center seeming clear and empty. Potassium iodide-iodine stains the contents of the middle cell deeply, but shows no contents whatsoever in the long terminal cell. Chloroiodide of zinc shows the middle cell stained dark yellow (the wall being cutinized and the contents protein),

but the long terminal cell wall only stains violet, while the cavity looks clear.

Loco weed leaves (dried) absorb 9.24 per cent of water, drops of water disappear when placed on them, and colored solutions (safranin, hæmatoxylin, eosin, and methylene blue) easily penetrate to the cell cavity. Haberlandt says that when such structures are present and the leaf is capable of absorbing much water (by weight) or drops of water when put on them, or there is quick penetration of colored solutions, "it is fairly safe to conclude that the hairs in question represent water-absorbing organs." Therefore I have concluded that these hairs function for the absorption of water in the form of dew or rain. The long cell gathers the moisture, the irregularities on its surface serving to keep the droplets from running off, then the middle cell with its contents conducts it towards the cells of the mesophyll. This middle cell has very dense contents, protein especially. The water may be taken along the terminal cell by imbibition, then drawn by osmosis through the middle cell into the leaf.

Cross sections of the leaflet show little difference in the upper and lower halves. The hairs and stomata (about thirty per square millimeter) are as numerous on one side as on the other. (Figs. 3, 4, and 5.) Palisade cells are arranged on either side of the central portion of the mesophyll, which contains the vascular tissues. It appears that the reflection of the sun from the ground is strong enough to stimulate the formation of palisade tissue on the under side of the leaf as well as to give light enough for the chloroplasts there to function. The terminal tracheids often have enlarged ends, which may serve for water storage. (Figs. 3 and 4.) A section of leaf seen through a microscope with a polarizer attachment shows only the cell walls of the hairs to look bright; nothing else can be seen in the dark field, and no crystals are in this way demonstrated in the leaf. The upper part of the basal cell and all of the outer cell walls of the epidermis are heavily cutinized. (Fig. 4.) A multiple epidermis is shown in a few places. The midvein of the leaflet consists of bast, phloëm and xylem.

The petiole has numerous bundles which supply the leaflets (fig. 6), one going out of the petiole into each petiolule.

There is a layer inside the walls of the bast fibers which stains reddish violet with chloroiodide of zinc, and yellow with potassium iodide-iodine. The lignified walls with both are yellow. With phloroglucin these linings stain red, but a little lighter than the walls. Methylene blue showed no mucilaginous modification.

These layers are therefore concluded to be inner layers of the bast which are not completely lignified, but still have cellulose in them.

With a polarizer, as well as potassium iodide-iodine or chloro-iodide of zinc, starch grains in the starch sheath are shown, but no crystals. Irregular broken spaces are often found in the center of the pith of the petiole. These do not seem to be mucilage channels.

STEM. The stem does not show distinct annular rings, even though secondary thickening is apparent. The phloëm is rather extensive (figs. 8, 9, and 10), and is filled with food materials. Fig. 9 shows three of the smaller bundles in a stem and fig. 10 a longitudinal section of one of the larger bundles. Sieve plates can not be seen. The older portion of the stem has thick cork. This cork tissue gives the suberin test with Sudan III and the lignin test with phloroglucin, as if the suberized membrane were partially infiltrated with lignin.

ROOT. The root shows annular rings better than the stem. Between the rings of water tubes are rings of wood parenchyma cells, which are unlignified, as are also the wood fibers. The water tubes are the only part of the root which is lignified. (Fig. 12.) The phloëm is great in extent. (Figs. 11 and 13.) The older portion of the root has cork similar to that of the stem.

INFLORESCENCE. The peduncle is, like the petiole, made up of many bundles which are to supply the pedicels and bracts at their bases. As these are opposite, the peduncle contains four less bundles above their separation than below. There is relatively more bast in this portion of the plant than in any other. There are one or two rows of lignified parenchymatous cells, making a ring connecting the bundles, near the outer edge of the xylem.

The flower is a typical one of the tribe Galegeæ of the Leguminosæ. The pod is curved, with a partition extending in from the convex side and separating the two cells. In the center of the tissue of the pod is a layer .3 millimeter thick of bast fibers which encircle it, thus making it very stout.

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DESCRIPTION OF PLATES.

PLATE I.

FIG. 1. Hairs taken from a leaf. × 45.

FIG. 2. High-power drawing of hair from leaf, showing: *t*, terminal cell; *m*, middle cell; *b*, basal cell. × 450.

FIG. 3. Surface of a leaflet of loco weed, showing: *t*, tracheal system within the tissue; *e*, epidermal cells; *s*, stoma; *c*, cuticular ring at base of hair; *h*, hair. × 90.

FIG. 4. Cross section of a leaflet at the edge, showing: *e*, epidermis; *b*, basal cell of hair; *h*, hypoderm; *p*, palisade cells; *s*, stoma; *vb*, vascular bundle. × 115.

FIG. 5. Cross section of a leaflet at the midrib. × 115.

PLATE II.

FIG. 6. Diagram of a cross section of the petiole, showing: *e*, epidermis; *b*, bast tissue; *p*, phloëm; *x*, xylem. × 40.

FIG. 7. Cross section of a vascular bundle of the petiole, showing: *e*, epidermis, with *h*, hair; *c*, cortex; *s*, starch sheath; *t*, bast tissue; *p*, phloëm; *x*, xylem; *pi*, pith. × 90.

PLATE III.

FIG. 8. Diagram of a cross section of the stem, showing: *b*, bast tissue; *p*, phloëm; *x*, xylem. × 15.

FIG. 9. Cross section of vascular bundles of the stem, showing: *b*, bast tissue; *p*, phloëm; *x*, xylem; *mr*, medullary ray; *pi*, pith. × 90.

FIG. 10. Longitudinal section of a vascular bundle of the stem, showing the same tissues. × 90.

PLATE IV.

FIG. 11. Diagram of a cross section of the root, showing: *c*, cork; *p*, phloëm; *x*, xylem; *mr*, medullary ray. × 17.

FIG. 12. Cross section of a portion of the xylem of the root, showing: *mr*, medullary ray; *wt*, water tube; *wp*, wood parenchyma; *wf*, wood fibers. × 90.

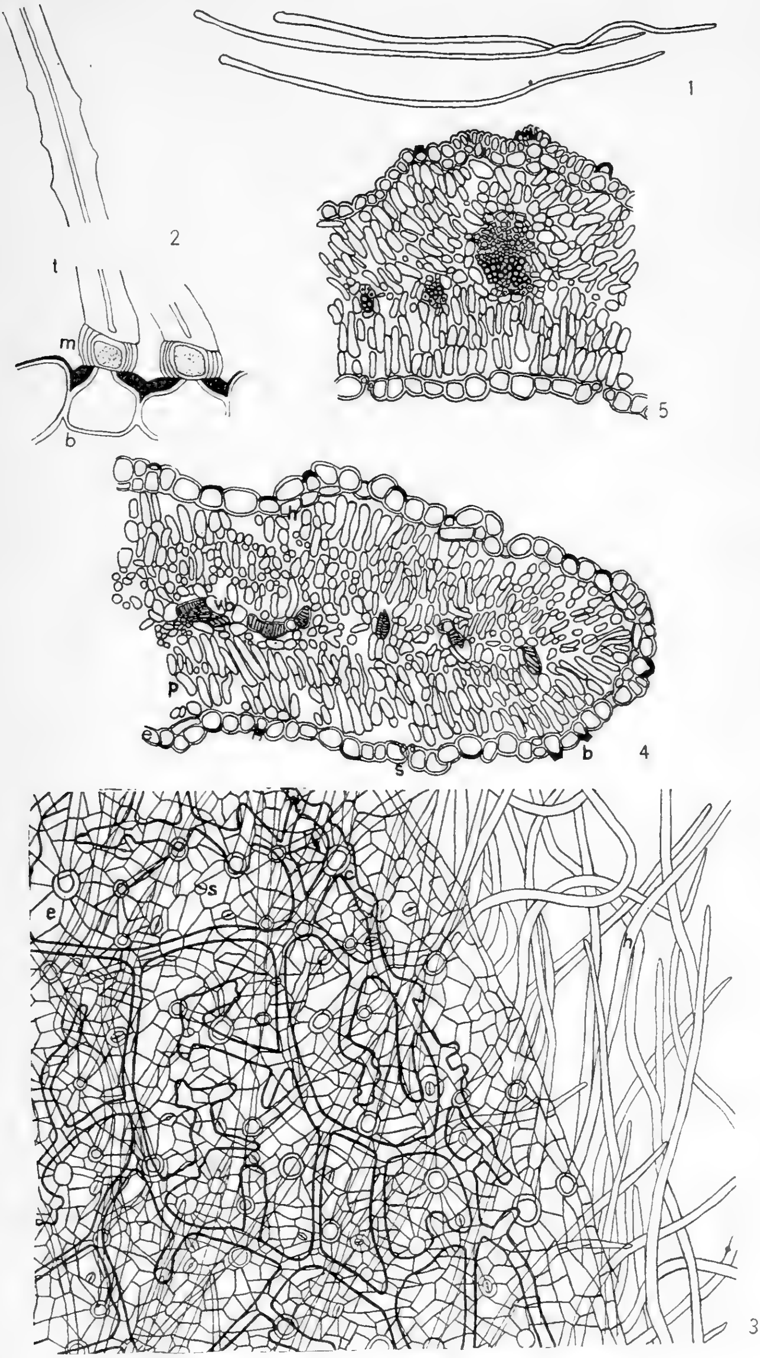
FIG. 13. Cross section of a portion of the vascular bundle of the root, showing: *p*, phloëm; *mr*, medullary ray; *x*, xylem. × 90.

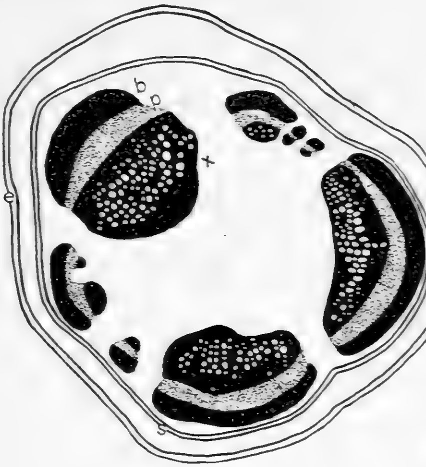
FIG. 14. Diagram of a cross section of the peduncle, showing: *e*, epidermis; *b*, bast tissue; *p*, phloëm; *x*, xylem. × 30.

FIG. 15. Cross section of a vascular bundle of the peduncle, showing the same tissues. × 90.

ASTRAGALUS MOLLISSIMUS.
Neva Ritter.

PLATE I.





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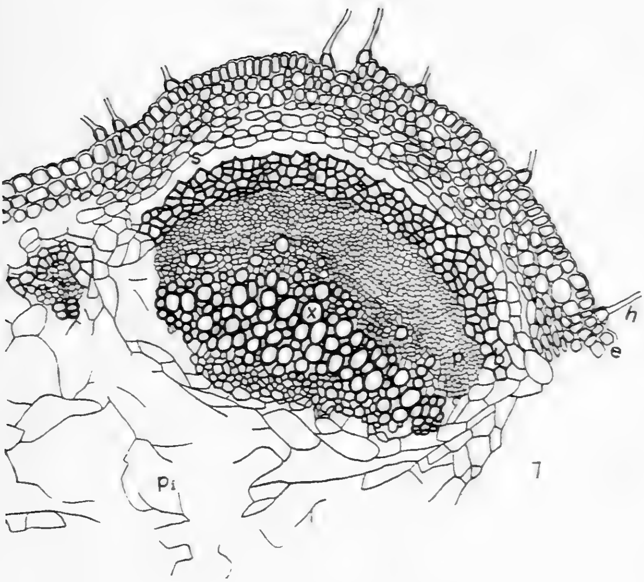

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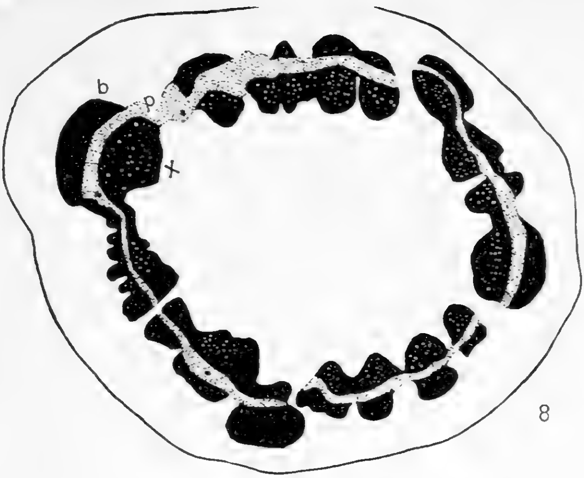
ASTRAGALUS MOLLISSIMUS.
Neva Ritter.

PLATE III.



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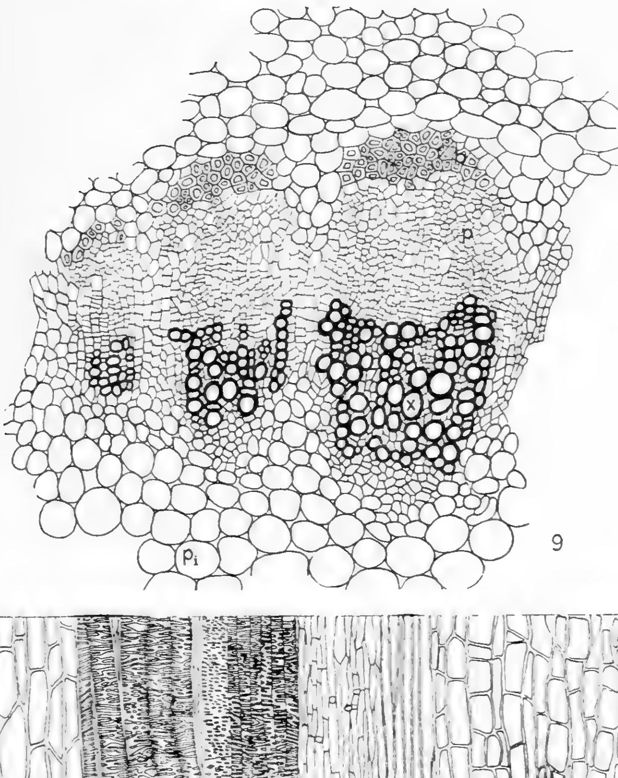

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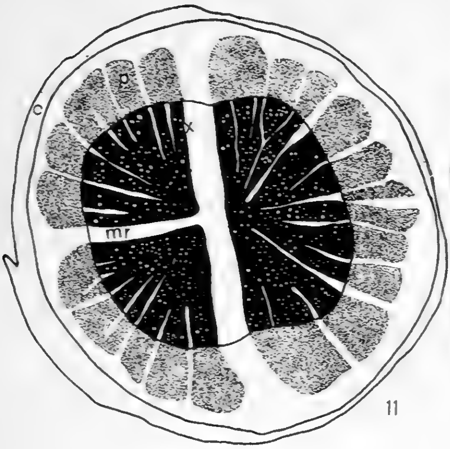
ASTRAGALUS MOLLISSIMUS.
Neva Ritter.

PLATE IV.



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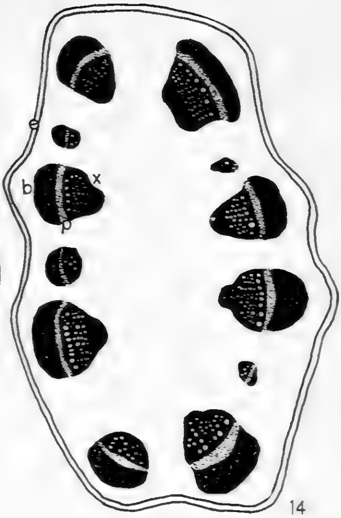

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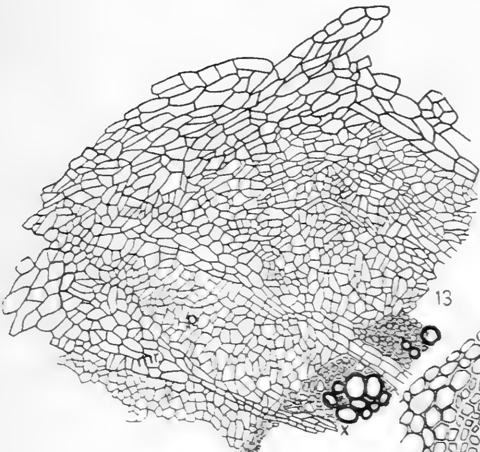

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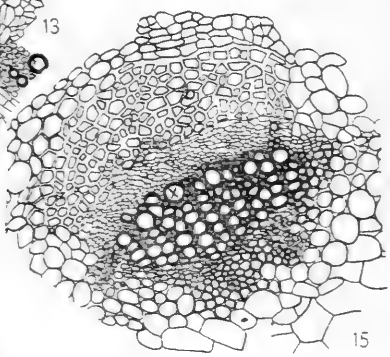

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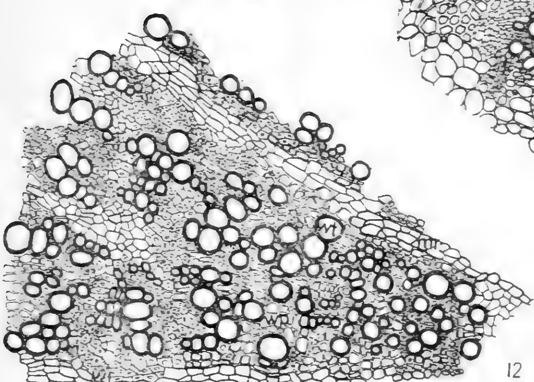

12

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Ecological Morphology of *Abutilon theophrasti*.

BY LOUISE LUCKAN.

ABUTILON THEOPHRASTI, commonly known as velvet leaf, is an upright-growing mallow which may attain the height of six feet. It thrives at the edge of cultivated fields or in rich waste lands, such as lots, where it often occurs in dense patches.

During the summer of 1916 drought conditions prevailed for a month. The last rain of early summer fell about June 28 or 29, and the drought was not broken until the 26th of August. This meant that plant life would probably suffer for lack of water for at least a month. Many plants showed the effect of this lack of moisture very much, but *Abutilon theophrasti* remained fresh and green and attained its normal height. Here, then, an interesting problem offered itself as to what provisions the plant had made to withstand the drought.

The material for this study was collected on the south slope of the University campus. Both preserved and fresh material was studied. The standard histological methods were used and the drawings were made by the use of the camera lucida on the microscope and with the projectoscope.

ANATOMY.

The Leaf.

The leaves, borne on long, slender petioles, are roundish heart-shaped with an acuminate apex, and when full grown measure from four to five inches across. When the leaves are picked off they soon wither. During the hottest part of the day the edges of the leaf curl, but it requires only a short time for leaves to regain their turgor.

The shoots of young plants, each bearing from four to five leaves, were cut off, the cut surface sealed with wax and the shoots allowed to dry for an hour or more. These were then weighed separately and placed in a saturated atmosphere to see if they would regain their turgor or gain in weight. One set was left standing for forty hours, and then, after the leaf surfaces had been dried with filter paper, they were weighed. Those placed in the saturated atmosphere gained 15.11 per cent in weight, while those painted with distilled water and then placed in saturated atmosphere gained 18.95 per cent in weight. Another set was allowed to dry for three hours and was then brushed over with distilled water. The average of these tests showed a gain of 19.46 per cent in two hours. This shows that the plant has some power to absorb moisture from the atmosphere, especially if dew is present. Haberlandt ('14) gives two examples, *Convolvulus cneorum* and *Centaurea argentea,* where water is absorbed by hairs of the leaf. The wilted leaves gained 10 and 13 per cent, respectively, when immersed for twenty-four hours. In comparing the percentage gained and the conditions of the experiment, *Abutilon theophrasti* is much more efficient.

The leaf is dorsiventral, with the palisade tissue a single layer of cells on the upper side. Large thin-walled water-storage cells over the smaller veins interrupt this layer (fig. 1, *d*). Both surfaces of the leaf are thickly covered with four types of hairs, namely, two types of clothing hairs, one of which is stellate and the other an unbranched single-celled form, and two types of glandular hairs, one long and the other short. The stellate hairs, the most characteristic for the family, are the common clothing hairs, and these are found in great numbers and almost exclusively over the veins. The rays of the stellate hairs vary in number and length. They are united at their bases in the plane of the epidermis; and there being no stalk cells, these hairs do not rise far above the epidermal surface. The walls of the basal portion are relatively thick and contain pits (fig. 6). A ray cell (fig. 5) has the cavity diminishing toward the apex until in some cases it is entirely closed there. The walls of the rays show up as being composed of two layers—a thin outer cuticle imperfectly developed and a thick inner portion which the chloroiodide of zinc test gave evidence of being slightly infiltrated with cutin. The basal portion of these hairs stain a bright red with safranin, and yellow with chloroiodide of zinc, indicating cutinization, or possibly lignification; but give no color reaction with phloroglucin or ani-

line sulphate, and very little, if any, with Sudan III. In one test with the chloroiodide of zinc the inner portion of the cell wall of the basal region stained purple, indicating cellulose in the position shown in fig. 5. Some of these hairs showed nuclei situated in the basal part, but very little cytoplasm could be demonstrated.

Haberlandt, in his discussion of multicellular absorbing hairs, makes the statement: "If such a hairy covering is easily wetted and rapidly absorbs drops of water; if, further, the hairy leaf rapidly recovers its turgidity when immersed or besprinkled in the withered condition; if, finally, places for the entrance of water through the hairs are indicated by the presence of thin-walled basal cells with abundant protoplasmic contents, it may be safely assumed that the hairs in question serve to some extent for the absorption of water." The imperfect cutinization of the walls, above noted, would allow the water to pass to the inside of the hair. The structure of the stellate hairs, together with their occurrence only on the veins, and the amount of water absorbed by wilted leaves, as mentioned, lead me to believe that these hairs are water-absorbing hairs.

The other form of clothing hair is like a single ray of the stellate type; here the pits in the basal portion show up plainly (fig. 7).

The glandular hairs are of two kinds; one is long, being made up of from twelve to fifteen cells, while the other is only four to five cells in length. The basal cell of the long hair is enlarged (figs. 3 and 4). The cell just above it has its side walls cutinized throughout, so that it shows up as a bright-colored ring when stained with Sudan III or chloroiodide of zinc. The remaining cells of the hair are provided with a very thin cuticle. The apex is rounded out, and here drops of oil collect as it is secreted. The short glandular hair has its cells little differentiated, but the basal cell is slightly larger than the neighboring cells (fig. 8). These smaller hairs occur along the midrib and the larger veins, and Nestler ('99) says in some of the species of *Abutilon* they function as hydathodes, or hairs which excrete water. The hairs are advantageously situated for this, and as they contain living protoplasts they could possibly function in this way.

The stomata are not specialized, and are found in greater numbers on the lower epidermis, where they average 300 per square millimeter as compared with 250 on the upper surface.

The radial and outer walls of the epidermis are not especially thickened, but the inner wall of some of the epidermal cells becomes much thickened and mucilaginous and protrudes down into

the palisade tissue (fig. 2). The inner cell walls of the lower epidermis are not as thick as those of the upper, and only a few are mucilaginous. The mucilage may be so abundant, in varying degrees, that the inner wall at first glance might seem to be a second layer of epidermal cells, entirely filled with mucilage.

The mucilaginous deposits probably serve as a place of storage for water, absorbing a large amount when there is excess moisture in the leaf, and then gradually giving this up to the palisade tissue when the water supply runs low. I found no constant relation between these cells having the mucilaginous inner wall and the hairs, to indicate that water absorbed from the atmosphere by the hairs would be delivered to them for storage.

The midrib and the larger veins project prominently from the lower surface of the leaf, and the greater portion of this projection is composed of large thin-walled cells surrounding the vascular bundle (fig. 13). Kuntze ('91) describes mesophyll cells on the upper side of the vein, which break down to form large mucilage channels in many of the Malvaceæ. In the cross sections of the veins examined no channels were found, and only a single cell situated in this position showed mucilage (fig. 13, *m*). There are, however, on the upper surface a large number of epidermal cells, outlining the veins, which have a mucilaginous content (fig. 12). Therefore we may conclude that mesophyll cells of the midrib, as well as the mucilage cells, are good places for water storage, and are probably used as such.

The Stem.

The stem structure follows closely the type form of the dicotyledonous stem. The young stem is covered with both types of clothing and glandular hairs described, under the leaf. These hairs extend perpendicular to the surface, so that the young stem looks quite fuzzy. The epidermis of the stem has regular cells, the walls of which are not thickened to any great extent. The cuticle on the outer wall is very thin, and I found no cutinized layer which would aid in keeping in the water.

The cortex is made up of four regions—an outer thin-walled parenchyma, a collenchyma, a second thin-walled parenchyma, and the starch sheath (fig. 15). The outer thin-walled parenchyma is made up of three layers of radially enlongated cells. The collenchyma tissue is composed of three layers, forming a broken ring, with the gaps opposite the medullary rays. This arrangement allows the water to pass in and out to the epidermis more

readily than if it were to diffuse through the thickened walls of the collenchyma. The second layer of thin-walled parenchyma of the cortex is only one or two cells deep and is often crushed up against the collenchyma. The starch sheath is apparent, but the cells do not contain starch.

The bast strands of the pericycle are in groups, separated by thin-walled cells. The cell walls of the bast are lignified. Besides the bast of the pericycle there are several layers of secondary bast strands formed by the cambium and interspersed in alternate layers with the secondary leptome elements (figs. 14 and 15).

This growth develops a wedge tapering outward, so that in cross section the stem has wedges of bast and phloëm alternating with wedges of medullary ray, which taper in the opposite direction (fig. 14).

The medullary rays are only one to two cells wide in the xylem region of the stem, but where they extend out through the phloëm portion of the vascular bundle they broaden radially, so that here they are from four to six cells wide (fig. 15). The medullary rays of the stem do not contain large amounts of starch.

The phloëm is conspicuous, for there are between eight and ten layers of cells between the inner bast strands and the cambium.

Although this plant is an annual, the xylem of the stem seems to be made up of rings of growth due to alternate layers of tracheal tubes and xylem parenchyma (fig. 15).

The pith is permanent in the stem, increasing with the other tissues, so that in mature stems the pith has a diameter of one centimeter. In the younger pith the outer cells are filled with starch grains, and among these cells filled with starch are mucilage channels, or sometimes mucilage cells (fig. 14). These channels are formed by the cell walls becoming mucilaginous and some of them breaking down. They may be made of only one cell in the cross section, or several cells adjoining may break down so that the channels or pockets are of different sizes. The pith cells contain many calcium oxalate crystals, usually compound, which are very noticeable in the young cells, where they fill the cell cavity.

The Root.

The root is a long taproot with few secondary roots. The root resembles the stem in having large wedges of bast. The medullary rays, especially in the region of the xylem, are well filled with starch. Cork is present as an outer covering of the older portions of the root (fig. 16).

In the thin-walled parenchyma of the cortex, droplets of oil are of frequent occurrence, and these were discovered to be held in the stroma of spherical elaioplasts, which in unstained sections appear simply as highly refractive bodies. When treated with chloroform or ether for twenty-four hours and then tested with stains for oil, no oil was demonstrated, but irrigation on a slide with solvents of oil for ten to fifteen minutes did not cause all of the oil to disappear. Sections from celloidin material, which had been fixed with one per cent chromacetic acid, tested with Sudan III, alkanin and chloroiodide of zinc, showed these bodies as globular masses reacting as oil. Strasburger ('13) makes the statement that the chromacetic acid fixitive causes percipitation of the stroma of elaioplasts and renders the oil less soluble. This may explain oil remaining in the stroma of the elaioplasts through the celloidin process in which solvents of oil are employed. Safranin-hæmatoxylin stain and the three-color stain showed these bodies as purplish, spherical, reticulate structures. The elaioplasts in the cells of the root sometimes lie next to the nucleus, but a constant relation was not found. The cytoplasm in the older cells of the cortex is only a thin layer lining the wall, so that there the elaioplasts are against the wall; usually only one to a cell (figs. 17 and 18).

Beer ('09) in his work on *Gaillardia* sustains the theory of Wakker ('88) that the elaioplasts are formed by the aggregation and fusion of the leuocoplasts in the cell. His work seems to give conclusive evidence for this mode of formation in the plant studied. He found elaioplasts in different stages of development, and observed living cells in which the process was going on where cell divisions had long since ceased; but Politis ('11), in his work on the development of the elaioplasts in *Ornithogallum umbellatum* bulbs, maintains that they are formed by the cytoplasm, almost simultaneously with nuclear division. He states that the stroma of the elaioplasts stains with the nuclear stains, reacting like the nucleolus; and since they also are dissolved with nuclear solvents, he maintains the elaioplasts are of nuclear origin and gives the fact of the close association with the nucleus and the chemical reactions as basis for this conclusion.

In *Abutilon* I found elaioplasts were present in the actively growing parts, such as floral organs, growing apices of stem, young seedlings, barely sprouted seeds, and also in root sections in all stages of development. When the older parts of the stem were tested no elaioplasts could be demonstrated. The presence

of elaioplasts in the growing apex of the stem and the absence of them in the older stem seems to support Politis' theory that they are active only a short time and are then used up by the plant tissues, but the fact that the elaioplasts are present in the cells of the cortex of the old root is against this.

In regard to their origin, I am not able positively to confirm either theory. I find leucoplasts aggregated about the nucleus in the cells of the soaked seed, but I could not find intermediate steps, for it seems that in my material the elaioplasts do not form oil until they have attained a spherical form and ultimate size. Certainly the hairs of the *Gaillardia* studied by Beer are unusually favorable subjects for showing the course of elaioplast development.

Politis found the elaioplasts usually present in the epidermis of the floral organs, but their occurrence in other organs was inconstant. He says they are an active organ of the cell during growth. When active the elaioplasts have a rotating motion in the cell; when at rest the elaioplasts may assume various forms as a last phase of development. He found elaioplasts present in the following species of Malvaceæ: *Hibiscus syraicus, Althea rosea, Malva rotundifolia, M. sylvestris, Gossypium arboreum, Gothea cauliflora.*

MICROCHEMISTRY OF CELL CONTENTS.

The Leaf.

Leaves that had been in bright sunlight, brought in and tested for starch with iodine, showed the presence of starch. Similar leaves boiled in Fehling's solution showed crystals of cuprous oxide, indicating the presence of sugar in the form of monosaccharide.

Sections of leaves in Sudan III overnight showed palisade cells orange yellow, but not good demonstration of oil. The large glandular hairs showed droplets of bright orange red, indicating oil. Leaf sections soaked in chloroform and then tested with Sudan III did not give the red color reaction.

Volatile oil tests were made by collecting the distillate from leaf tissues on cover slips rinsed in chloroform, which were then treated with Sudan III, and iodine fumes. On cover slips without the distillate, but otherwise treated in the same way, no oil was demonstrated; on those with the distillate, however, a good positive test was shown, indicating the presence of volatile oil in the leaf.

Sections of leaves were treated with methylene blue as a mucilage test. The inner cell wall of some of the epidermal cells took the stain (figs. 1, 2*b*).

Sections of the leaf heated in Millon's reagent showed brick-red contents in the palisade and spongy parenchyma cells.

Sections treated with fresh ferric chloride solution gave no tannin reaction.

Compound crystals of calcium oxalate were demonstrated by the use of hydrochloric acid, in which the crystals disappeared without effervescence. These crystals were common in the border parenchyma of the large veins.

Stem.

Sections of older stems treated with iodine showed the presence of much starch in the outer cells of the pith and also in the medullary rays.

Fehling's solution used on sections of the stem showed cuprous oxide crystals, and these increased in number and size when sections were left in a incubator for several hours, thus indicating the possible presence of saccharose and glucosides in addition to glucose.

Young stems showed the presence of oil in elaioplasts, but in older portions of the stem the sections gave no oil reactions. The glandular hairs of the stem and the petiole have drops of oil collected at their apices. Sudan III stains these drops, collected on a slide, a bright red. When left on a slide on a 50° oven for twenty-four hours the oil did not disappear. It is thus probably fatty oil.

Protein tests were made with Millon's reagent, chloroiodide of zinc, and iodine, showing protein present only in the region of the phloëm and cambium. Methylene blue showed mucilage present in the pith and a very little in the cells of the cortex, and when fresh sections of the stem were placed on the slide and water applied to them, swelling and finally solution occurred in the secondary thickenings of the walls of some of the pith cells.

Calcium oxalate crystals are present in cells of the cortex and young pith.

Sections treated with ferric chloride gave no evidence of tannin.

Sections treated with saturated copper acetate solution for three weeks failed to show the presence of resin.

Alkaloid tests were made with potassium iodide and chloroiodide of zinc. Other sections soaked in alcoholic tartaric acid, a solvent of alkaloids, were compared with fresh sections. No brown precipitate was demonstrated, leading to the inference that no alkaloids were present.

Root.

Starch is present in the medullary rays. Methylene blue showed very little mucilage in the root. It was present only as a thin film in a few of the cell walls of the cortex. Fatty oil is present in the stroma of elaioplasts. Fresh sections soaked in solvents of oil, choloroform, ether and xylene, and then stained with Sudan III, showed the oil had been dissolved out and the stroma was partially collapsed. Tests for volatile oil were negative.

Protein tests are not decisive, because the cell walls of the lignified tissue became brick red with Millon's reagent. When these walls were tested with aniline sulphate and phloroglucin, they gave the lignin reaction.

Seed.

Sections of soaked seed treated with Sudan III and iodine showed a large amount of oil in the endosperm and also in the embryo.

Sections of seed treated with Millon's reagent turned red in the region of the endosperm and cotyledons, indicating the presence of protein as a reserve food. Other sections treated with iodine showed no starch was present.

Methylene blue showed no indications of mucilage.

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DESCRIPTION OF PLATES.

PLATE I.

FIG. 1. Section of leaf showing part of a large vein. × 300. *a*, upper epidermal cell; *b*, mucilaginous wall; *c*, palisade cell; *d*, water-storage cell; *e*, spongy parenchyma; *v*, vein; *f*, stellate hair; *g*, glandular hair.

FIG. 2. Cross section of leaf. × 285. *s*, stoma. The rest of the index is the same as in fig. 1.

FIG. 3. Long glandular hair. × 200. *a*, apex, *b*, basal cell; *c*, protoplast shrunken away from wall.

FIG. 4. Lower portion of long glandular hair from section of the petiole. × 325. *b*, basal cell; *d*, cutinized wall; *e*, cuticle.

FIG. 5. Longitudinal section through stellate hair, showing peculiar reaction in chloroidide of zinc; stipled, orange yellow; shaded, purple. × 325.

FIG. 6. Cross section of leaf showing stellate hair over vein; index same as fig. 1. × 325.

FIG. 7. Simple clothing hair from section of petiole. × 325.

FIG. 8. Short glandular hair. × 325. *a*, plasmolysed protoplast; *b*, basal cell.

PLATE II.

FIG. 9. Surface view of leaf, showing relation of hairs to the veins. × 200. *a*, long glandular hair; *b*, short glandular hair; *c*, stellate hair; *d*, stoma; *e*, vein.

FIG. 10. Tangential section of leaf. × 200. *a*, palisade cells; *b*, border parenchyma; *c*, tracheal tube.

FIG. 11. Tangential section of leaf, showing frequency of the mucilage cells. × 200. *r*, stoma; *h*, hair; *m*, mucilage.

FIG. 12. Tangential section of leaf, above a vein, showing frequency of mucilage cells there. × 200.

FIG. 13. Cross section of large vein. × 100. *a*, thin-walled cells; *p*, phloëm; *x*, xylem; *m*, mucilage.

PLATE III.

FIG. 14. Cross section of stem, showing the regions and the wedged effect of bast and medullary rays. × 15. *c*, cortex; *b*, bast; *p*, phloëm; *x*, xylem; *m*, mucilage; *me*, medullary ray; *s*, starch in pith.

FIG. 15. Section of stem, showing rings in xylem. × 150. *a*, epidermis; *b*, thin-walled parenchyma; *c*, collenchyma; *d*, second thin-walled collenchyma; *e*, starch sheath; *f*, bast fiber; *g*, leptome elements; *h*, phloëm; *i*, cambium; *j*, water tubes; *k*, wood parenchyma; *l*, pith; *m*, mucilage channels; *n*, medullary ray.

FIG. 16. Cross section of root. × 15. *c*, cork; *b*, bast; *p*, phloëm; *x*, xylem; *mr*, medullary ray; *r*, rootlets leaving the root.

FIG. 17. Cells of cortex of seedling root. × 325. *e*, elaioplasts.

FIG. 18. Cells of cortex of older root. × 325. Showing elaioplasts.

ABUTILON THEOPHRASTI.
Louise Luckan.

PLATE I.

ABUTILON THEOPHRASTI.
Louise Luckan.

PLATE II.

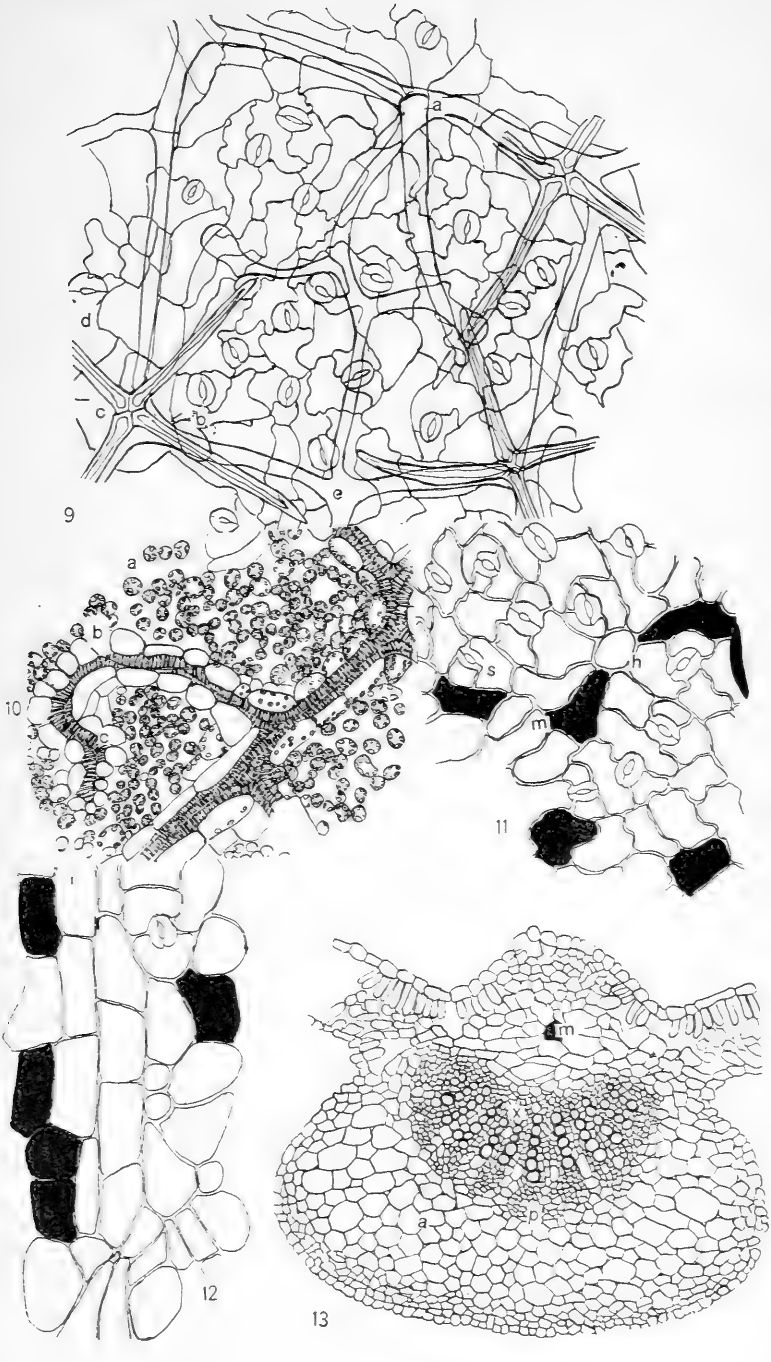
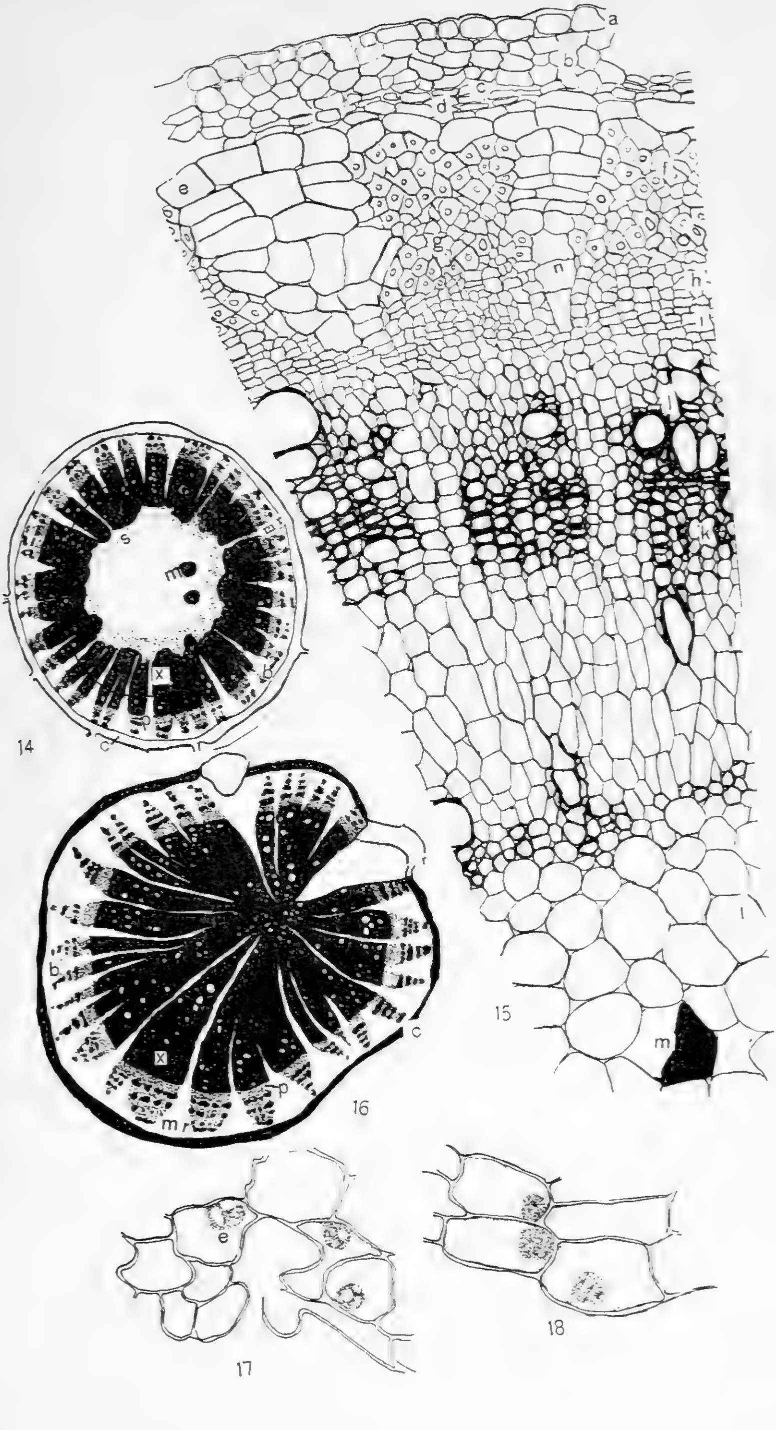


PLATE III.



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VOL. X, NO. 10.] JANUARY, 1917. [WHOLE SERIES VOL. XX, NO. 10.

Eryops; Eryopsoides, Gen. Nov. from the New Mexico Permian.

BY HERMAN DOUTHITT.

SKULL STRUCTURE.

THE statements made herein are based upon the study of eight skulls in the University of Chicago collection, some incomplete, and some only partly uncovered at the present time; one incomplete skull loaned from the Yale Museum for the purpose (No. 826); one skull and fragmentary material from the University of Kansas collection; and descriptions by Branson, Case and Broom. Shortly after this work was undertaken, in the fall of 1913, a paper by Broom appeared which covered to a large extent the same field. The morphological part, therefore, is presented mainly as a review and criticism of the work of Broom.

The structure of the upper surface of the skull was found to offer no disagreements from the results made known by the investigations of Branson, Case and Broom, and need not be discussed here. A few slight disagreements were found, which represented probably mere individual differences.

The occipital region and base of the skull were found to agree with the accounts of Broom, except that there is considerable evidence that the supraoccipital is present. No separation could be made out of the elements designated by Broom as basisphenoid and sphenethmoid, but there appears no reason for doubting his determination. As regards the supraoccipital, evidence of its presence is provided by one small, apparently immature, skull. The sutures extend from just dorsad of the condyles, dorsad and laterad, the supraoccipital thus forming more than one-half of the border of the foramen magnum. None of the larger skulls at hand give satisfactory evidence of its presence, though several are well preserved.

It seems, therefore, that the supraoccipital was present in *Eryops*, but that in adult life the element was fused with the exoccipitals. Its presence would be logically expected, since the postparietal is clearly excluded from the foramen magnum. To have the two exoccipitals meet and fuse above would be decidedly unusual; and even if no trace of sutures were to be found, it would be logical to interpret the upper part as supraoccipital and the lateral as exoccipital. The old assumption that the supraoccipital is absent in the Amphibia can not be given any consideration, for the writer has made it out in *Trematops*, and it will probably be found in other Temnospondyli when looked for.

Von Huene (1912) supposed the supraoccipital to be present, and showed it in his drawings of the occiput. The part he designated as supraoccipital, however, forms less than one-third of the element.

The palates are poorly preserved in all of the Chicago specimens, from which the matrix had been removed, but as far as their elements could be made out, they agree with the descriptions of Case and Broom. As regards the dentition of the palatine, transverse and vomer bones, however, there is difference of opinion. Branson and Broom concluded that each of these bear one large tooth at a time, and explain the cases of two occurring at once as being due to the development of a second tooth, to replace the first, before the first happens to be shed. Case believed that there were normally two on each bone, with which view the writer is agreed. The number of cases in which two teeth are present and indistinguishable as to size or appearance in the specimens at hand, and in published drawings available, seems to show that two is the normal number, and that a less number is due to one or both being lost in preservation. The following table shows the conditions found:

Element.	Number examined.	Number having two teeth.	Number having none.	Number having one.
Vomer	16	5	9	2
Palatine	15	6	5	4
Transverse	13	4	6	3

It will be seen that two teeth are preserved about as often as one. These two, it may be mentioned, are similar in size and appearance in nearly every case. The fact that there are so often no teeth at all suggests strongly that these were broken off and lost, either before or after death, but more probably afterwards, and that where only one tooth is present the other has been thus lost. Owing to the large size and prominence of the teeth, a slight

amount of shifting about of the skull after death must have resulted in their being broken off, and indeed they must have been often broken off in life. The presence of fresh scars indicates the same fact. Where several scars are present, the extra ones will present a different appearance, owing to the healing of the broken surfaces.

Broom speaks of the surangular as an element of the lower jaw, and leads us to suppose that it is present as a separate element. Were this true it would be the only case known of an amphibian with a separate surangular bone. A careful examination, however, of several good jaws of the Chicago collection shows not the slightest evidence of the separation from the articular of the part of the jaw so designated. That this portion of the articular of the Amphibia was once a separate element in their ancestors, and corresponds to the surangular of reptiles, seems probable; but the fusion in *Eryops* is as complete as in other Amphibia. A well-preserved jaw of the Chicago collection shows the three coronoid bones as described by Broom.

A COMPARISON OF TEXAS AND NEW MEXICO MATERIAL.

The vertebrate faunæ of the Texas and New Mexico Permian are widely different from each other. Aside from the genus *Eryops*, only two genera, *Edaphosaurus* and *Diadectes*, are recognized to occur in both. *Dimetrodon* and *Clepsydrops* have been reported from the New Mexico Permian, years ago, but the negative evidence of later, more careful investigations is against their presence. Moreover, it is not unlikely that more complete specimens will show that those remains that have been referred to *Diadectes* represent really a closely allied but distinct genus. With such slight similarity between the faunæ of the two regions, there is especial need to make careful comparative studies of the specimens from the two regions that have been referred to these genera, in order to determine whether they are really generically identical.

Material and information concerning the New Mexican representatives of *Eryops* are scarce. Marsh (1878) first reported *Eryops* from New Mexico, but supposed he was dealing with the remains of a reptile, and described them under the name of *Ophiacodon grandis*. He gave us no information of value as to structure. Cope, in 1881, gave us the following description of *Eryops reticulatus*, without figures:

"The most prominent peculiarity of this species is seen in the neural spines, which are not expanded at the summit, as in *E. megacephalus*, but have rather contracted apices, Another character is the sharply reticulate

sculpture of the maxillary bones. The species is much smaller than *E. megacephalus*, or even than *T. insignis*, and the extent of the ossification of the vertebral elements is intermediate between the two species. The inferior surfaces of the intercentra are smooth, and the diapophuses are compressed. The occipital condyles are depressed, and not very well distinguished inferiorly. The humeri have expanded extremities, with enlarged epicondyles, well-developed condyles, and no epitrochlear foramen. Width of occipital condyles, m. .016; elevation of dorsal vertebræ, .024; width of intercentrum, .011; length of intercentrum (below), .207; five maxillary teeth in .015."

According to Case, the material upon which the description of Cope was based was mingled with the remains of other animals. Of Cope's material only the intercentra are known to-day, according to Case. We can not be certain, therefore, that the spines described by Cope did not belong to some other animal. Williston (1911) described briefly Marsh's material, but made no anatomical studies.

The present comparative studies are based upon two incomplete and poorly preserved skulls from New Mexico, one from the Yale Museum (No. 826), and one from the collection of the University of Chicago; and ten skulls from Texas, in the museum of the universities of Chicago and Kansas, and the published drawings of Case and Broom for specimens in the American Museum. Unfortunately, the skulls from New Mexico are in such poor condition that no satisfactory measurements or determinations of sutures could be made. The skulls are apparently shorter and broader than those from Texas, but this can not be established. There is one constant difference which is discernible, however, which is, in the opinion of the author, of generic rank. This is in the matter of the arrangement of teeth on the palatine, transverse and vomer bones.

In the skulls from New Mexico the two large teeth on each of these elements are without exception transverse in arrangement, while in the skulls from Texas they are without exception longitudinal with respect to each other, where both are present, or where fresh scars are present. Specifically, the condition in the skulls from New Mexico is as follows: Two transverse bones, one with two teeth arranged transversely, one with one tooth; three palatine bones, two with two teeth arranged transversely, and one with one tooth; four vomers, two with two teeth arranged transversely, one with one tooth and a fresh scar, arranged transversely, and the other with one tooth. In all the Texas skulls at hand there is not a single exception to the rule that the two teeth on each of these elements are longitudinal with respect to each

other, either where two teeth are present or where there are fresh scars.

Considering that there is not an exception in all the skulls or published drawings available, this character seems to indicate that the New Mexican specimens are distinct from those from Texas. No doubt, better-preserved material will show other important differences. If the materials described by Cope be of this animal, then the New Mexican specimens have the apices of the neural spines contracted, and differ in the character of the intercentra. The skulls at hand from New Mexico seem to be shorter and broader than those from Texas, but owing to the imperfection of the material this can not be proved. But until better material is secured we must rely upon this one character, which should be of generic rank. For the new genus the name *Eryopsoides* is proposed, and specimen No. 826 of the Peabody Museum is named as type. Whether Marsh's *Ophiacodon grandis* (1878) and Cope's *Eryops reticulatus* (1881) are the same species will perhaps never be known, since the type materials are lost; but since Marsh's name precedes, it should be adopted as the specific name for the New Mexico specimens referred to *Eryopsoides*.

While there is no particular interest in the mere fact of recognizing a closely allied but distinct genus, the recognition is in this case of considerable interest, since it shows that *Eryops* is not common to both regions. The faunæ of these regions, so far as known, have very little in common, *Edaphosaurus* and *Diadectes* being now the only forms recognized as common to both. It is not at all improbable that better-preserved specimens will show that the New Mexico specimens referred to *Diadectes* are really generically distinct, and that *Edaphosaurus* is the only genus common to both regions. This would indicate a faunal separation of the two regions, and the nature of the animals is such as to show that they developed parallel, rather than that they were separated in time, and one descended from the other.

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A Study of Several Strains of Pleomorphic Streptococci.

NOBLE P. SHERWOOD,

From the Department of Bacteriology of the University of Kansas, Lawrence.

KLEIN AND GORDON[1] isolated a polymorphic streptococcus from a series of scarlet fever cases and called it *Streptococcus scarlatina.* They considered it identical with the *Streptococcus conglomeratus* of Kurth.[2] Klein held that this streptococcus is causally related to scarlet fever in man and is wholly distinct from *Streptococcus pyogenes.* Gordon believed that both *Streptococcus pyogenes* and *Streptococcus conglomeratus* may play a part in the causation of scarlet fever, but that *Streptococcus conglomeratus* is the more important of the two, and that it occupies a position in the bacteriological kingdom between *Streptococcus pyogenes* and *Bacillus diphtheria.*

Winslow[3] mentions the fact that cocci isolated freshly from the mouth are particularly apt to show successive pairs of flattened cells and occasionally exhibit elongated rod-like cells, and that large cells sometimes appear in chains of smaller cells. This is probably a generally observed fact, although practically no mention is made of it in the literature.

Newman[4] emphasizes an observation of Gordon that frequently the streptococcus may morphologically resemble the Klebs-Loeffler bacillus.

Jean Broadhurst[5] has more recently observed large cells appearing in sugar-broth cultures of streptococci, and remarks upon the absence of reference to such variation in the literature.

Behring[6] investigated the *Streptococcus longus* and recognized four groups. Under group three he places Kurth's *Streptococcus conglomeratus* as one yielding or producing scaly flocks of sediment. Andrew and Horder[7] have classified as *Streptococcus anginosus* a pathogenic long-chained form, allied in other respects to *Streptococcus salivarius,* and bearing to it much the same relation which

Streptococcus pyogenes bears to *Streptococcus mitis*. They mention it as occurring in cases of scarlatinal and other forms of sore throat. It produces a flocculent deposit in broth, clots milk, reduces neutral red, forms acid in saccharose, lactose, and raffinose.

The enterococcus of Thiercelin, Escherich, Beeson[8] and others is a pleomorphic streptococcus that varies from the streptococcus of Gordon in its growth in broth, milk and on agar.

The object of this paper is to report upon a pleomorphic strain of the streptococcus isolated from chronically enlarged cervical lymph glands of a patient otherwise apparently in good health, and to compare this with eight other more or less markedly pleomorphic streptococci isolated from five cases of tonsilitis, two cases of bronchitis, and one case of infection on back of hand and with *Streptococcus pyogenes* and *Bacillus diphtheria*. The basis of comparison is upon morphology, staining reactions, cultural characteristics, action on carbohydrates according to Andrew's and Horder's classification, and complement fixation tests.

In November, 1912, a local physician requested a bacteriological examination of material from the cervical lymph glands of a patient with the following history: Male, age 26; had noticed twenty-six months previously the enlargement of the cervical lymph glands on the right side of the neck. Nineteen months later he attended a hospital clinic, drainage was established, and the case observed at intervals by the attending physician for seven months. During this time the glands continued to enlarge. At the end of seven months the patient went to his family physician, who suggested the bacteriological examination. No acid-fast organisms were found, but a pure culture of a marked pleomorphic streptococcus was obtained both from the glands and from the tonsils. At this time the glands on both sides were involved; the axillary and inguinal lymph glands were shotty. The physician advised a tonsillectomy, but the patient wanted a vaccine. Accordingly a vaccine was prepared. Three weeks after the administration of the first dose the swelling had disappeared and the patient was discharged. Three months afterward there seemed to be the beginning of a recurrence, a tonsillectomy was performed, and the patient has remained well to date.

The organism isolated had the following characteristics, which, in so far as morphology, staining reactions and general cultural characteristics are concerned, seemed to be identical with those of *Streptococcus scarlatina* of Klein and Gordon and the *Streptococcus*

conglomeratus of Kurth. It apparently varied somewhat from these in its action on some of the carbohydrates and glucosides and was not isolated from a scarlet fever patient.

MORPHOLOGY. A pleomorphic streptococcus, showing irregularities in size and shape of elements, every transition between coccus form and bacillus form. This includes wedge shape, spindle shapes, oval forms, club shapes, and tendency towards filaments in agar, gelatin and modified Loeffler's blood serum. In hanging drops there were conglomerate coherent masses.

STAINING REACTIONS. Stained readily by the ordinary aniline stains, intensely Gram positive and non-acid-fast. Metachromatic granules were not observed.

CULTURAL CHARACTERISTICS. Agar slant, 37° C., three types of colonies after twenty-four hours: (*a*) gray, granular, irregularly outlined colonies; (*b*) colonies quite similar but showing a confluent appearance; (*c*) colonies evidently younger and smaller, which have a fine frilling of chains around a more dense compact confluent center.

Gelatin, 20° C., non-liquefying.

Bouillon, 37° C., clear, coherent sediment in bottom of tube.

Litmus milk, 37° C., twenty-four hours, coagulated rapidly, usually with quite a solid curd, lower half of tube white, while upper half was pink.

Carbohydrates and glucosides. Dextrose, lactose, saccharose and raffinose acidified, while inulin, salicin and mannite were not attacked. Neutral red showed some reduction.

Russell's medium, acidified. When, instead of a central stab, a stab was made next to the glass, the growth assumed a typical skyrocket appearance, spreading out near the bottom of the tube. The lower part of the tube was decolorized.

POSITION ACCORDING TO ANDREW'S AND HORDER'S CLASSIFICATION. In the following table a comparison of the action of this pleomorphic streptococcus with other streptococci is given according to their action on various carbohydrates, glucosides and neutral red.

	Milk	Neutral red	Saccharose	Lactose	Raffinose	Inulin	Salicin	Coniferin	Mannite
Pleomorphic streptococcus	+	+*	+	+	+	–	–	......	–
Strep. equinus	–	–	+	–	–	–	+	+	–
Strep. mitis	A	–	+	+	–	–	+	–	–
Strep. pyogenes	A	–	+	+	–	–	+	–	–
Strep. salivarius	+	+	+	+	+	–	–	–	–
Strep. anginosus	+	+	+	+	+	–	–	–	–
Strep. fecalis	+	+	+	+	–	–	+	+	+
Strep. pneumonia	A	–	+	+	+	+	–	–	–

NOTE.—In the above table in the column for milk (+) signifies acid with clotting, (A) acid without clotting, (–) no apparent action. For neutral red (+) signifies reduction, (+*) partial reduction, (–) no action. Otherwise (+) signifies acid to litmus, (–) no action or alkaline.

Winslow[9] seems to think that the *Streptococcus scarlatina* described by Gordon and the *Streptococcus conglomeratus* of Kurth were the same as *Streptococcus pyogenes.* He bases his statement upon the further studies of Gordon upon this group from the standpoint of their fermentation reactions. It will be observed that the pleomorphic streptococcus described in this paper would, according to Andrew's and Horder's classification, correspond to *Streptococcus anginosis.*

Since this organism was isolated the author has made slides and cultures from 365 cases of tonsillitis occurring among students and faculty of the University and from other cases in the city, from several cases of bronchitis and one case of hand infection. In addition, fifty cultures and smears were made from the throats of apparently normal individuals. Streptococci with large cells and with rod-like cells were found very commonly in the cases of tonsillitis and frequently in bronchitis. Only a very few were obtained from the normal throats. These were from individuals subject to attacks of tonsillitis as a rule. Five strains were obtained from cases of tonsillitis, two from cases of bronchitis, and one from infection on back of hand of a member of the faculty, all of which showed marked tendency toward persistent involution and produced more marked conglomerate masses in the bottom of broth tubes. They correspond very closely in morphology, cultural characteristics and tinctorial reactions with the organism described above. From four of these cases fresh material was obtained and isolations of club-shaped organisms and chains with enlarged cells were made by Barber's pipette method for single

cell isolation. The individual organisms were inoculated into the moisture of condensation of agar slants, and after several hours the water was permitted to cover the surface of the slant. In this way growth was obtained. The author was unable to get very large individual coccus forms to grow satisfactorily, although Dr. F. Hecker has privately reported success. The resulting cultures from the above isolations showed as marked pleomorphic variations as the other cultures. As a rule, successive transfers in dextrose broth would yield uniform chains in time, but involution forms reappeared when transfers were made to solid media, especially if partially desiccated media were used. Very frequently beautiful chains could be obtained from the deeper part of the stab in Russell's medium when the stab was made next to the glass, while involution forms predominated upon the surface of the slant.

The *Streptococcus pyogenes,* and in fact the rest of the streptococcus group, is usually described as chains of cocci of comparatively uniform size, but varying in length of chain, pathogenicity, action on litmus milk, various carbohydrates, glucosides and neutral red.

Much work has been done which suggests that perhaps there are not so many different streptococci as has been generally thought, but that one or at most a few organisms make up the group and that these are very plastic and subject to much variation. Heineman[10] and others have concluded that *Streptococcus pyogenes* and *Streptococcus lacticus* are perhaps one and the same. Rosenow[11] has reported remarkably induced mutations in streptococci. He has converted hemolytic streptococci from many sources, such as erysipelas, scarlet fever, puerperal fever, arthritis, tonsillitis, milk, etc., into *Streptococcus viridans, Streptococcus mucosus,* and typical pseudopneumococci; *Streptococcus viridans* into *Streptococcus mucosus, Streptococcus hemolyticus* and *Streptococcus rheumaticus; Streptococcus mucosus* into *Streptococcus viridans* and *Streptococcus hemolyticus; Streptococcus rheumaticus* into *Streptococcus viridans* and *pneumococci.* In this work he made use of pure cultures isolated by Barber's pipette method for single cell isolation. Billings and Rosenow[12] record quite a remarkable observation of bacterial mutation from a bacillus to a coccus form. They report colonies on dextrose agar showing only bacillus forms yielded in subculture; a staphlococcus in pure cultures; and forms of the bacillus, either pure or in a mixture, anerobically on the same media.

Dr. Victor C. Vaughn,[13] citing the collected studies of Eisenberg on "Mutation in Bacteria," gives a splendid brief discussion of the subject. In conclusion he says: "Evidence of mutation in bacteria might be multiplied many times. It is shown in changes of form, in capsule formation, in production of spores, in alteration of virulence, etc., but I think that I have collected enough data to conclusively show that in bacteria acquired characters are in part at least inheritable."

The tendency toward pleomorphism was quite persistent for the streptococci reported upon in this paper. After seven months cultivation there was a tendency toward uniform chain formation, but decided involution forms would occur. The variation in morphology of streptococci in liquid media, such as mannite broth, saccharose broth, etc., reported by Jean Broadhurst[14] was much more temporary but quite interesting. She says: "The morphology of the individual cell may be likewise affected. In media not utilized, some of the chains are usually of full or increased length, and there is usually a small proportion of swollen organisms (rounded and elliptical) either in short chains or interposed here and there in chains composed mainly of normal organisms. When the media are utilized, there is, besides this swelling, a distinct tendency to abnormal shapes . . . Often, however, more varied forms are seen—organisms which may be actually pear-shaped, club-shaped or obtusely diamond shaped. These changes are most marked in mannite, though they may occur in other media. . . . . A normal appearance is effected at once by transplanting to plain broth." Jean Broadhurst also made another interesting observation, which was that a strain of streptococcus producing no change in litmus milk acquired the ability of producing acid and of coagulating the milk by being put into a capsule and passed through the intestinal tract of a dog.

Repeated attempts have been made without success to control the pleomorphism of these organisms. In view of the observation that involution forms appeared quite frequently upon partly desiccated solid media, it was thought that perhaps differences in osmotic pressures might be responsible for the variations. Accordingly bouillon containing different concentrations of dextrose were tried, as were also different concentrations of NaCl, but the involution could not be controlled or increased in slightly involuting strains. Then culture media containing different concentrations of HCl and NaOH were tried, with unsatisfactory results. Since in the first organism isolated it was possible to get

uniform chain formation under partial anerobic conditions, it was decided to try increasing the oxygen tension slightly above atmospheric and see if this had any effect upon involution. This gave unsatisfactory results, as well as an experiment in which the CO_2 content of the atmosphere in contact with the culture media was varied. These negative results naturally do not mean that these involutions can not be controlled, as no doubt that time and patience or good fortune would yield positive results. I might say, however, that some of my work on another problem has suggested that perhaps the pleomorphism on the partially desiccated agar was due to the salts that crystallized out on the surface of the agar. It is hoped that this may be checked up more fully in the future.

Even if involution forms could be produced at will under one set of conditions, it would not necessarily follow that these were the conditions holding forth in the body under which pleomorphism occurred or persisted. The variation of the morphology of these organisms from typical streptococci have been termed involution forms, largely because (1) these organisms seem to prefer, as a rule, to grow and act as streptococci under artificial conditions of laboratory cultures; (2) the streptococci as a group is known to be very plastic, mutations occurring in many different ways; (3) similar though more transient variations in morphology have been observed to occur in pure cultures of streptococci; (4) since sufficient evidence is not apparent to change the classification given them by Kurth, Gordon and Klein.

The similarity to *B. diphtheria* noted by Gordon and emphasized by Newman is at times quite striking. Not enough strains of these organisms were studied to warrant a statement that none might contain metachromatic granules, since it is a well-known fact, as emphasized by Graham Smith,[15] that not all strains of virulent *B. diphtheria* have metachromatic granules. None were observed in the cultures studied. I know that frequently these pleomorphic streptococci may be mistaken for *B. diphtheria* when smear preparations only are examined. A bacteriologist experienced in diphtheria examinations would not make the mistakes, but when one realizes that many relatively inexperienced individuals make throat examinations, either for themselves or others, it is quite possible for errors to be made. These errors would be upon the positive side and might or might not be objectionable, depending upon the tolerance of the individual for the foreign protein, any benefit derived from it, the expense incident thereto,

and the suffering entailed. Four of the eight severe cases of tonsillitis were given 10,000 units of antitoxin and made a rapid recovery. Of the other four cases, two cleared up in time though not nearly so quickly, and two developed ear infections and responded to vaccine treatment. All were suspected diphtheria cases. It might be said, in the first place, that the number of cases is too few for the results to be of value; second, that in the four cases receiving antitoxin, they would have made a quick recovery anyway; third, that in these four there were foci of infection with *B. diphtheria* in the trachæ (nose and throat examinations were made); fourth, that the diphtheria antitoxin was beneficial because of a relationship between the diphtheria group and this group (these organisms were not toxin producers in vitro); fifth, the benefit resulted from nonspecific protein therapy as emphasized by Muller, Weichardt, Miller and others for many infections. If the marked improvement resulted from the injection of the antitoxin, I would rather incline to the last explanation, perhaps, until a more definite relationship is proven between *B. diphtheria* and the streptococci than I have found. It is, however, true that Denny, Corbett and others have described strains of *B. diphtheria* that they call streptococcal forms, and the pleomorphic nature of *B. diphtheria* is well known. From the standpoint of morphology *B. diphtheria* has been frequently reported as showing involution forms similar to these pleomorphic streptococci. G. S. Graham-Smith[16] describes the involution forms of *B. diphtheria* as follows: "After prolonged growth on a suitable medium, or more quickly on an unsuitable medium, diphtheria bacilli become considerably altered in shape. Their appearance becomes more irregular and very large forms are frequently encountered. Many become greatly swollen at the ends and develop enormous club-shaped masses which stain deeply, while the rest of the bacillus may stain badly or have irregular patches of deeply stained protoplasm in it. Others become pear-shaped or globular, while some retain their general shape but become thicker throughout. Others again show large globules at their ends, while the rest of the rod appears as a faintly stained line. Specimens which take up the stain very badly are common. Some bacilli may be represented by small round masses like cocci, or by a chain of such masses, when they look like streptococci. In fact, under such conditions every variety of shape and form and staining capacity may be met with." The cultural characteristics of *B. diphtheria* are well known. It is generally considered that the organism ferments dextrose but not

lactose. Graham-Smith,[17] however, reports numerous strains of virulent diphtheria bacilli which produced acid with coagulation of Hiss's serum water medium containing lactose. The diphtheria bacillus grown in dextrose broth gives a typical streptococcus effect, clear broth with flocculent precipitate settling down. Macroscopically the colonies on agar are quite similar to normal streptococcus colonies. Its action in neutral red is variable. It must be remembered that one of the strong objections to classification of any organisms according to fermentation reactions is because of the fluctuating variability that one frequently meets with. I did not think that the pleomorphic streptococci isolated were identical with *B. diphtheria*, but I was interested in the apparent and suggested relationship between the streptococcus group and the diphtheria group, as suggested by Gordon and others. I next decided to compare the several strains of pleomorphic streptococci with each other and with *B. diphtheria* and *Streptococcus pyogenes* by means of the complement fixation test. I wanted to include a known culture of *Streptococcus anginosis*, but was unable to obtain it at the time. This work was then conducted as follows:

ANTIGEN. Two kinds of antigen were employed. In both cases the organisms were grown in plain agar. For one of the antigens suspension of the growth in isotonic salt solution was used. For the other type of antigen the growth was teased off in distilled water and suspension allowed to autolyze and an equal volume of double-strength salt solution added.

HEMOLYTIC SYSTEM. Human red blood cells and the corresponding hemolytic amboceptor.

TECHNIQUE. The technique, barring of course the differences in antigens, was similar to Noguchi's modification of the Wassermann reaction. As a preliminary to this work all of the animals were checked up for normal complement-fixing antibodies with each of the above antigens, and all were negative.

Following vaccination with the respective strains of organisms, the results showed cross-fixation for all of the strains of the pleomorphic streptococci, but no fixation when any of these pleomorphic streptococci were used as antigen with anti-*Streptococci pyogenes* immune sera or *B. diphtheria* immune sera, nor was the converse true. Neither was there any cross-fixation between *B. diphtheria* and *Streptococcus pyogenes*, although these antigens gave 4 plus reactions with their respective immune sera. In other

words, no relationship was apparent or suggested between these pleomorphic streptococci and *B. diphtheria* and *Streptococcus pyogenes* as suggested by Gordon. It might well be that a relationship could exist and the complement fixation test be unreliable. Meyer,[19] Aronson,[20] Kerner,[21] while not working with complement fixation test, decided that immune sera gave variable results and were not consistent. Some recent work on the streptococcus group in press is quite desirable. The complement fixation test has not been a uniform and decided success as a means of differentiation, but nevertheless is of great value in many instances.

Since this paper was finished two papers by Mellon on the diphtheroid group of organisms have appeared. He reports upon a pleomorphic organism isolated from the lungs which shows all variations from bacillary form to a streptococcus form. In morphology and many cultural reactions his diphtheroid is similar to the pleomorphic streptococcus I have been working with. Both are pleomorphic, Gram-positive, nonmotile organisms giving a clear broth with heavy sediment, coagulate milk, produce acid in dextrose, lactose, sucrose. The diphtheroid organism produced acid in salicin and inulin, whereas the pleomorphic streptococcus I am reporting on failed to do so. Mellon states that in broth cultures at one stage of development there are numerous bipolar bacilli with large granules. From this I presume that metachromatic granules were observed. I did not observe these occurring in the pleomorphic streptococcus studied. Doctor Mellon has placed his organism among the diphtheroids because of immunological, cultural and morphological reasons; however, he says that "unless great care is used in handling the recently recovered bacillary form, it will almost immediately revert to the diplococcus form when transplanted even to solid media." His experimental work and mine, made in attempts to control the pleomorphism, give largely negative results.

I should say that we were both working with closely related if not identical organisms. In his papers he suggests the immunological relationship between his organism and the group of diphtheroids, of *B. diphtheria* and the streptococci. As a result of complement fixation work, I found no relationship between the pleomorphic organisms I was studying and *B. diphtheria* or *Streptococcus pyogenes.*

SUMMARY AND CONCLUSIONS.

1. That a pleomorphic organism quite similar to if not identical with *Streptococcus scarlatina* of Gordon and *Streptococcus conglomeratus* of Kurth was isolated by me from chronically enlarged cervical lymph glands of an individual having no history of scarlet fever. This organism showed all transitions between bacillary form and chains of diplococci.

2. That a vaccine was apparently beneficial, and that since tonsillectomy no recurrence has taken place. The tendency for recurrence after three months is another example of the transient immunity resulting from streptococcus vaccination. It is a well-known fact that streptococcus infections do not confer a lasting immunity. This is one thing that should give us pause in ascribing to streptococci the primary cause of such diseases as scarlet fever and measles where a comparatively lasting immunity results.

3. That a similar organism was isolated from a hand infection, from two cases of bronchitis, and from five out of 365 cases of tonsillitis. Frequently pleomorphic streptococci showing other colony types on agar and Loeffler's blood serum were also observed in tonsillitis cases.

4. That some of the involution forms of this streptococcus might be mistaken for *B. diphtheria* by other than a well-trained observer. This is of importance in view of the many relatively inexperienced individuals doing laboratory work either for themselves or as a commercial proposition. It is of added interest in view of the observations of Gordon and Newman, suggesting a relationship between the streptococcus group and the diphtheria group. This has more recently been emphasized by Mellon.

5. That during the diphtheria epidemic in Kansas City in 1914 a number of patients showing only pleomorphic streptococci in nose and throat smears and cultures, nevertheless recovered rapidly following administration of 10,000 units of antitoxin. Similar results were obtained in a small series of cases in Lawrence. This may or may not mean anything. If the apparent beneficial results were real and not a coincidence, and if no unfound foci of diphtheria existed, it might not indicate a relationship between these organisms and *B. diphtheria,* but could be another example of nonspecific protein therapy as reported by Muller, Miller, Weichardt and others.

6. That according to Andrew and Horder's classification the pleomorphic organism I am reporting upon appeared to be the same as *Streptococcus anginosus.*

7. It ultimately seemed to prefer the streptococcus (chains of diplococci) morphology.

8. Complement fixation tests showed no normal complement fixing bodies, in the normal rabbits used, for any of the pleomorphic streptococci, *Streptococcus pyogenes* or *B. diphtheria.*

9. Complement fixation with respective immune sera showed no relationship between the pleomorphic streptococcus and *B. diphtheria.* This, however, does not necessarily prove no relationship.

10. While attempts to control the pleomorphism were largely negative, I have some results which suggest that the salts which crystallized out on the agar might be a factor in producing involution forms on the desiccated agar.

11. I feel that a healthy skepticism is well worth while in all work involving mutation, since errors in technique can lead to very erroneous conclusions. The work of Mellon seems to be thoroughly and carefully done and is worthy of consideration. His results, even more than mine, point to an intermediate group between the streptococci and diphtheria.

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The Function of the Supraglenoid Canal.

BY HERMAN DOUTHITT.

SEVERAL months ago the writer was discussing with Professor Williston the presence in *Diplocaulus* of the supraglenoid foramen, a structure which has been recognized in nearly all Permian reptiles, and in the Temnospondyli. Professor Williston stated that he had been surprised to note that the same foramen occurs in the lizards, where its presence had apparently been completely overlooked. He suggested that the writer study its function in the lizard, with the view likewise of determining its function in the early Tetrapoda.

With this end in view, the writer has made a careful study of the collared lizard, *Crotaphytus collaris*. Part of the material used was secured from the Dyche Museum of Natural History. I wish here to acknowledge the courtesy of Mr. C. D. Bunker in placing this material at my disposal. Fresh material has likewise been collected, and the arteries injected.

The supraglenoid canal, or foramen, occurs in two distinct forms. In lizards and Temnospondyli, in most Cotylosauria at least, and in some Thermorpha, as *Edaphosaurus* and *Ophiacodon*, its external opening is on the posterior edge of the scapula, at the bottom of the supraglenoid fossa. In the lizard, and no doubt in the other forms, the foramen lies just laterad of the area of insertion of the long head of the triceps muscle. In the lizard, however, there is no fossa. The canal passes from the foramen upward and forward, to open finally upon the inner surface of the scapula. In *Crotaphytus* and *Varanus* this canal is of considerable length, the inner opening being well above the middle of the scapula.

In most Theromorpha, and in *Diplocaulus,* on the other hand, there is no canal, and the foramen is not on the posterior margin, but farther forward, on the flat surface of the scapula.

It would seem that the form and position occurring in the lizards is the primitive one, since it is the type of both the Temnospondyli and the Cotylosauria. Apparently, the lizard is the only mesozoic or modern tetrapod which has retained this structure. Gunther shows a foramen piercing the scapula of *Sphenodon* (article not available to the author), but two scapulæ at hand show no evidence of it.

In determining the function of this foramen the writer has dissected four specimens of *Crotaphytus collaris.* It was seen at once that the foramen was used for the passage of a blood vessel, and was not used by the nervous system. In order to determine the exact relation and identity of this vessel, the

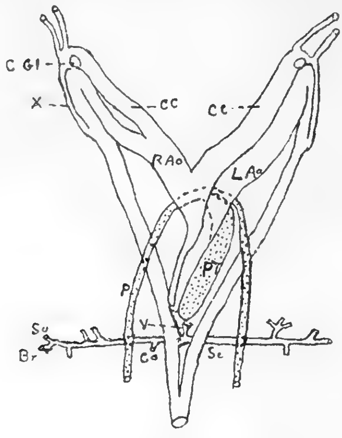

FIG. 1. Aortic arches and subclavian of *Crotaphytus collaris.* *Br,* brachiel artery; *CC,* common carotid artery; *C GI,* carotid gland; *LAo,* left aorta; *P,* pulmonary artery; *PT,* Pulmonary trunk; *RAo,* right aorta; *Sc,* subclavian artery; *Su,* subscapularis artery; *V,* vertebral trunk; *X,* Carotid-systemic connection..

subclavian and axillary arteries were traced out in detail. This very interesting system in the lizard has been traced out in detail for *Psammosaurus griseus* by Corti (1853). The writer does not have access to his account. Hoffmann's account in Bronn's Thierreichs is based upon Corti, but is necessarily condensed. It is not possible, therefore, to compare *Crotaphytus* with his account. Hoffmann makes no mention of the supraglenoid canal, from which it seems that it was not observed by Corti. Possibly the canal is not present in *Psammosaurus.*

In *Crotaphytus* (Fig. 1) the two subclavians come off from near the lower end of the right aorta by a single stem. After about 1 mm. this common stem divides, and the two subclaviæ pass directly laterad to the arm. At the point of their separation, in the median line of the body, the vertebral artery is given off as a single vessel. It runs directly forward on the ventral surface of the centrum for about 2 mm. and then divides into right and left vertebral arteries.

The costocervical axis leaves the subclavian just laterad of the centrum, and sinks at once into the muscles of the back.

Beyond the costocervical, the subclavian passes beneath the heavy *longus colli* muscle. Beneath the outer portion of this muscle it gives off two or three small branches which pass to the adjacent anterior regions. These should represent the thyrocervical axis. A little further laterad another vessel leaving the subclavian on the posterior side is no doubt the internal mammary artery.

The axillary artery divides almost immediately. The brachial continues down the arm in the usual manner. The lateral branch, which is without doubt the subscapularis, passes towards the space between the *latissimus dorsi* and a muscle which corresponds in position and relations to the *teres.* The subscapularis divides almost at once. The most posterior branch divides soon into three branches, which spread over the surface of the last-named muscle. The other branch turns towards the axis of the limb, over the proximal portion of the long head of the triceps, and into the space between this muscle and the humerus. Here it divides into several branches, one of which passes through the canal in question, to supply the subscapularis muscle.

There can be no reasonable doubt but that the supraglenoid foramen and canal in all forms in which it occurs, has the same function as the lizard; that is, that it serves as a passage for a branch of the subscapularis muscle. In mammals the subscapularis artery proper passes laterad of the scapula and its muscles, while only a minor branch passes to the subscapularis muscle. In the lizard, however, this branch seems to be the most important one.

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The Chromosomes of *Nomotettix*.

BY MYRTLE FRANCES RAYBURN,

University of Kansas.

THE Tettigidæ are a small, clearly defined group of grasshoppers known as the "grouse locusts." *Nomotettix* is one of the twenty-one genera comprising the members of this family found in North America. Of these, the cromosomes of representative species from four different genera, *Choriphyllum, Acridium, Paratettix* and *Tettigidea,* have been studied by Robertson ('15 and '16) and Harman ('15). *Nomotettix* will be the fifth genus to be added to this series.

In his comparative study of the chromosomes of Tettigidæ, Robertson found a uniformity of numbers, and to a great extent of size relations throughout nine species belonging to the four genera above mentioned. In the species of *Nomotettix, cristatus* Scudder, which I have here studied, I find the same chromosome numbers and practically the same lengths of chromosomes.

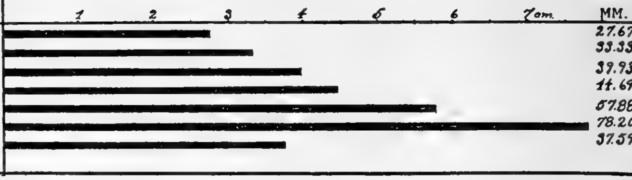
The individuals used were from material collected near Lowell, Mass. The testes were fixed in Flemming's fluid and stained in Haidenhain's iron-hemotoxylin. Drawings were made with a camera lucida, and are here reproduced at a magnification of 2600 diameters.

The chromosomes of *Nomotettix* are of the rod-shaped type and are thirteen in number in the spermatogonia of the male. They may be readily arranged in a series of six pairs besides the accessory. There are two large pairs (Nos. 6 and 5), two intermediate pairs (4 and 3), and two smaller pairs (2 and 1). Usually the sex chromosome shows a woolly appearance, making it easy to distinguish. Its size is third in the series, coming between the 2's and 3's (autosomes).

CHROMOSOMES OF NOMOTETTIX.

Myrtle F. Rayburn.

NUMBER OF THE CHROMOSOMES	LENGTH IN MM =X3900	RELATIVE LENGTHS	NOMOTETTIX SPERMATOGONIA MM.
1	11.72	9.82	27.67
2	14.12	11.83	33.33
3	16.90	14.17	39.93
4	18.92	15.86	44.69
5	24.50	20.54	57.88
6	33.10	27.75	78.20
X	15.92	13.34	37.59



In the table for *Nomotettix cristatus* Scudder, the first six horizontal bars represent the relative lengths of the six pairs of autosomes, and the seventh the percentage that the sex chromosome is of the total sum of the lengths of the autosomes.

In the relative lengths of chromosomes, the genus *Nomotettix* is more nearly like the genus Acridium than *Paratettix* or *Tettigidea,* as shown in particular by the measurements for the fifth and sixth pairs of chromosomes. Compare the relative lengths of these, 20.54 to 27.75, for the spermatogonia of *Nomotettix,* with those for the same chromosomes in *Acridium,* the genus to which *Nomotettix* is most nearly related taxonomically. Again, compare the relative lengths of the smallest and intermediate pairs with those of *Acridium.* It will be seen that there is not so very much difference. The smallest pairs, whose lengths are 9.82 and 11.83, compare very similar to the lengths 10.48 and 11.49 for *Acridium granelatus* or 11 and 11.06 for *A. incurvatus.* The intermediate pairs, 14.17 and 15.86, are slightly larger than in *Acridium,* the species *ornatus* excepted. These numbers in *Acridium* are as follows: For *granulatus,* 13.31 and 14.08; for *incurvatus,* 13.4 and 14.3; for *obscurus,* 13.3 and 14.1; but for *ornatus* 14.63 and 15.86.

The difference in length between the longer of the intermediate pairs and the shorter of the two longest pairs is about one-half as great as in the species of *Acridium.* Compare the ratio 15.86 to 20.54 of *Nomotettix* with 14.08 to 22.48 of *A. granulatus,* 14.3 to 22.5 of *A. incurvatus,* 15.86 to 21.47 of *A. ornatus* and 14.1 to 22.1 of *A. obscurus.* This is one point at which there is a rather marked disagreement between *Nomotettix* and *Acridium.*

In comparing the relative lengths of these chromosomes, as shown by the tables of my text figure, with those of Robertson for *Paratettix* and *Acridium,* it may at once be seen that

Nomotettix is farther away from *Paratettix* than from *Acridium.* For instance, there is a much less extreme range of length shown in *Paratettix* than in *Nomotettix.* Compare the ratios 9.82 to 27.75, the relative lengths of Nos. 1 and 6 of *Nomotettix,* with 11.4 to 23.6 and 11.4 to 23.7 of *Paratettix cucculatus* and *texana,* respectively, and also with 10.48 to 28.14 and 10 to 29.4 of *Acridium granulatus* and *obscurus,* respectively.

Likewise, the sex chromosome in *Nomotettix* is relatively shorter than in the species of *Paratettix.* Here it ranks between the second and third autosomes in spermatogonia, having the value of 13.34. In the spermatogonia of *Paratettix* it ranks between the second and third autosomes, but has the value of 13.9. In the first spermatocytes its rank is between the fourth and fifth autosomes and has a value of 17.2 in *Paratettix cucculatus* and 17.8 in P. *texana.* In *Acridium* it ranks either between the second and third autosome or below the first autosome. Its length is very short, having the value of either 11.95 or 8.7 in spermatogonia, or for first spermatocyte 13.45 (ranking between second and third, but low), 11 (ranking with No. 1), 7.9 (ranking below No. 1), and 12.09 (ranking between 2 and 3). It will be seen that in so far as size of the sex chromosome is concerned, *Nomotettix* is nearer to *Acridium* than to *Paratettix.*

As regards relations with the genus *Tettigidea, Nomotettix* is about the same distance away as *Acridium.* In this genus the two long chromosomes are relatively not so long, 22.3 and 24.6, and are more nearly equal in length, while in *Nomotettix* they are very unequal in length, as in Acridium. The sex chromosome in *Tettigidea* ranks fifth in the series, while in *Nomotettix,* as already mentioned, it ranks third.

CONCLUSIONS.

1. *Nomotettix* agrees with all other genera of the family Tettigidæ in having in the male six pairs of autosomes and one sex chromosome.

2. It agrees with those genera of the family so far examined in that the pairs of autosomes readily arrange themselves according to length into three groups—two shorts, two intermediates, and two longs.

3. In the relative lengths of the autosomes this species of *Nomotettix* agrees more readly with species of *Acridium* than

with species of *Paratettix*. This is to be expected, since externally the body characters of *Nomotettix* are more nearly like those of *Acridium* than of *Paratettix*. Likewise, this species of *Nomotettix* is much farther away from those of *Tettigidea* than from those of either *Acridium* or *Paratettix*. Again, this is to be expected from the fact that *Tettigidea* belongs to an entirely different subfamily, the Batrachidinæ. *Nomotettix*, *Acridium* and *Paratettix* belong to the subfamily Tettiginæ.

4. The sex chromosome may be recognized in spermatogonial divisions by its woolly appearance.

5. The chromosomes of *Nomotettix*, when compared as to numbers, relative sizes, etc., with those of other genera of Tettigidæ, furnish evidence decidedly in favor of the hypothesis that chromosomes are individual self-perpetuating elements.

This work was done under the direction of W. R. B. Robertson.

JUNE 1, 1917.

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EXPLANATION OF PLATE.

Magnification at which drawings were made, × 3900. Reproduced here at × 2600. Small arabic numerals indicate the autosomes in the order of their size, from smallest to largest. In spermatogonia there are two of each size. The sex chromosome is indicated by an x. The numeral preceding the x indicates that the sex chromosome in size occurs between the second and third autosomes.

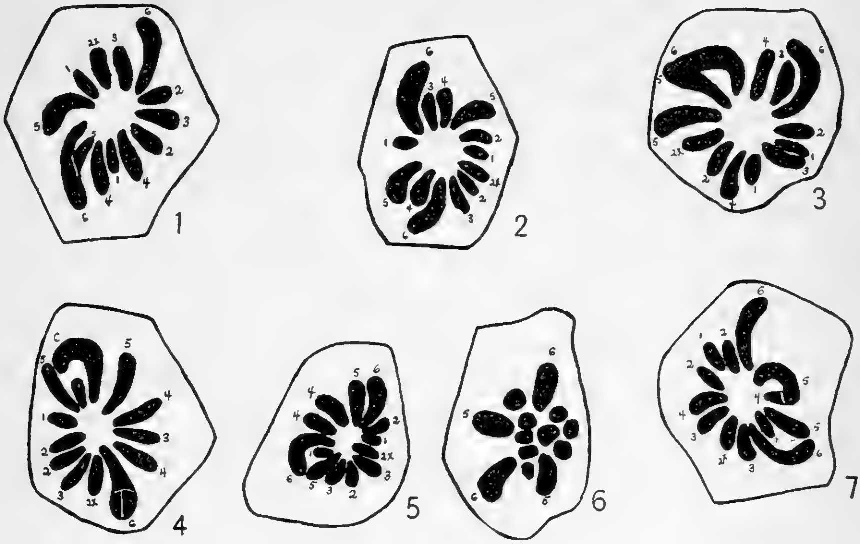
PLATE I.

Nomotettix cristatus Scudder.

FIGS. 1 TO 7. Spermatogonia dividing, metaphase stage.

CHROMOSOMES OF NOMOTETTIX.
Myrtle F. Rayburn.

PLATE I.



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Chromosome Studies IV: A Deficient Supernumerary Accessory Chromosome in a Male of *Tettigidea parvipennis.*

W. REES BREBNER ROBERTSON,
University of Kansas.

THE normal number of chromosomes of the species of *Tettigidæ* ("grouse locusts") so far examined is thirteen and fourteen in the male and female, *i. e.*, twelve autosomes and either one or two X-chromosomes, respectively. (Robertson '16; Rayburn, '17.) The subject of this investigation is a specmen which possesses the secondary sexual characters of a male, yet has fourteen chromosomes. What makes the case still more striking is the fact that the extra chromosome is probably an X-chromosome. On measurement, however, it was found to be shorter than its mate by between one-fifth and one-fourth the normal length (figs. 15, 17, etc.). As will be seen, it is probably to be considered a supernumerary, but deficient, accessory chromosome.

Its occurrence in the individual is uniform for all cells found dividing, somatic or germinal. In somatic cells it is not so readily identified in every case yet the fact that the number fourteen may always be clearly counted indicates its presence when other means fail. The somatic cells found containing it were from "fat body," follicle wall, and *vasa efferentia* tissues. The chromosomes in these cells are large and widely separated. The drawings indicate their actual positions in most cases (figs. 1 to 5). No difficulty or doubt was had in making the count here. Of course, counts in somatic cells could be obtained only from tissues surrounding the testes,

since these were the only tissues that had been taken with the testes from the body of the animal at the time of cytological preservation. The carcass itself unfortunately was preserved in a weak solution of formalin. The fact however, that "fat body" cells and the cells of the testicular follicles and of the *vasa efferentia* show fourteen chromosomes is reason for thinking that this number would likely have been found in all somatic cells.

In the germ cells (spermatogonia, figs. 6 and 7; first spermatocytes, figs 8 to 21; and second spermatocytes, figs 22 to 27) this chromosome is uniformly present. It is here that, on account of the singular behavior of accessory chromosomes normally exhibited in spermatogenesis stages, a clew is first obtained as to the probable nature of this supernumerary body which resembles in every way an accessory chromosome. Its characteristics are as follows:

(1) It may be recognized along with the accessory in synapsis and growth stages by its condensed condition (figs. 8 to 16).

(2) In "bouquet" of synapsis, intermediate finely threaded or netlike, and early prophase stages of the first spermatocyte, it always lies near the wall of the nucleus, which is characteristic of the accessory chromosomes (figs. 8 to 13).

(3) It condenses ahead of the other chromosomes in prophases of the first spermatocyte (figs. 14 to 16).

(4) It has a tendency to pair side to side with the accessory during parasynapsis stages when other chromosomes are similarly pairing (figs. 8 to 11). This occurs in about from 65 per cent to 75 per cent of cells. At this time both the accessory and the supernumerary have the form of a right-handed corkscrew like spiral (fig. 8). At later stages, they lie not so closely together, though there is evidence, in many of the cells, that they are in some way attached to each other (figs. 14 to 19). The synapsis seems to be most intimate at the pointed ends, which, judging from the general position in the cell and from the direction of orientation of the ordinary chromosomes, I have a surmise may be the distal ends. Further evidence of the association or pairing which occurs in synapsis is afforded by their behavior in the first spermatocyte division (figs. 17, 18, 19). In some cases (fig. 17) they are traveling to the same pole closely approximated to each other; in other

cases (figs. 18, 19) they are traveling to opposite poles, but separating from each other much like the members of autosome pairs that have been in synapsis.

(5) When the conjugated pairs of chromosomes (tetrads) arrange themselves in the metaphase of the first spermatocyte division, the supernumerary body passes like an accessory, undivided to one pole, going either to the same pole as the accessory chromosome (figs. 17, 21), or to the opposite pole (figs. 18, 19, 20).

(6) The supernumerary appears in one-half of the second spermatocytes either with the accessory or without it (figs. 22 to 27).

(7) It divides in this division as does the accessory chromosome (figs. 26, 27). One-half the spermatids get it and one-half do not. Four sorts of spermatozoa accordingly are formed.

From the characteristics here given, it is evident that this body is probably an accessory chromosome. If it occurred in these cells in the absence of the normal accessory (No. 5*x*) it certainly would be taken for that body. It fills all the specifications for the accessory of *Tettigidea* except size. An idea of the difference in size may be gotten by comparing the lengths of the two chromosomes in figures 8, and 15 to 21. The proximal end, from which the spindle fiber springs, seems to be normal, but the distal end appears somewhat abnormal (figs. 14*a*, 15, 17, 18). It seems likely that this chromosome is a descendant of an X-chromosome which at some previous polar body formation failed to separate properly from its mate, losing thereby a portion from its distal end. An incomplete daughter chromosome such as this might result. In this connection it may be said that it behaves very much like the deficient No. 4 chromosome described in Studies III (Robertson, 1915), whose peculiar structure and behavior was accounted for in this way.

In the literature on supernumeraries, the nearest approach to this chromosome are the cases described by Stevens in *Diabrotica soror* and *D. 12-punctata* (1908 *b*, 1912 *a*) and in *Ceuthophilus* (1912 *b*). Normally in these species there is a large unpaired heterochromosome (accessory) in the male and two such in the female similar to what occurs in Orthoptera. Stevens found about 50 per cent of the males of the

Diabroticas to have from one to five supernumeraries and 20 per cent of the males in *Ceuthophilus* to have one or more supernumeraries. Her conclusion was that these bodies were probably related to X-chromosomes, descended from fragments of X-chromosomes that had arisen through irregularities in the maturation division at some previous time. Wilson regarded his supernumeraries in *Metapodius* as duplicates of the Y-chromosome, *i. e.*, of the smaller member of the idiochromosome pair. No such Y-chromosome has been described for Acrididæ or Locustidæ. In addition, the irregular behavior of this supernumerary body (*s*) with reference to the accessory chromosome ($5x$), in going either with it or not to one pole in the first spermatocyte, is evidence against its being a Y-chromosome. This was also true of the *Diabroticas* and *Ceuthophilus.* It differs, however, from the latter two cases in this: that no cell has been found showing this body dividing in first instead of the second spermatocyte division, as was true in a few cases in the *Diabroticas* and *Ceuthophilus*. Otherwise it behaves very much like the supernumeraries of these forms. It seems warrantable to consider it as belonging to the X-chromosome rather than the Y-chromosome category.

If this body is in reality an accessory chromosome, and one that has lost from the distal end one-fifth or one-fourth of its length, and if it is also to be considered functional in so far as the portion present is concerned, we may regard it as throwing some light upon the question as to how much and what portion of the accessory in the family *Tettigidæ* is concerned with sex-determination. In the first place, that the sex-determining genes are probably limited to only a portion of the accessory chromosome in the genus *Tettigidea,* at least is to be inferred from a comparison of the relative lengths of the chromosome in the different genera of the family to which the genus belongs, the chromosome varying from eight in *Acridium* to fourteen or fifteen in *Paratettix* and eighteen or nineteen in *Tettigidea.* This supposition is of course based upon the assumption, first of all, that the X-chromosome is to a large degree similar in constitution throughout the family. That this is true we have reason to believe from the fact that these genera which appear to be so closely related taxonomically possess chromosomes (both autosomes and allosomes) which have a very great degree of similarity in number, form, and relative size (Robert-

son, '16; Rayburn '17). Such could only arise if the chromosomes of the group are considered as genetically continuous and related. The same applies to the X-chromosome. Further evidence that sex chromosomes may be similary constituted throughout a series of related species is afforded by the work of Metz ('14, 16*a*, 16*b*, 16*c*, 16*d*) on the *Drosophilas*, which has shown that not only one plan of structure, in so far as relative sizes, etc., is concerned, may run through the chromosomes of each species of a genus, but, what is still more striking, that each gene has probably the same locus with reference to other genes along the length of the chromosome throughout the various species. If such be the case in the *Drosophilas* it seems a probability that the same might be true of the accessory chromosome among the genera and species of the *Tettigidæ*. Then, we are justified in surmising that, since in the genus *Acridium* the sex-determining chromosome has a value of 8, in the genus *Tettigidea*, where its length is relatively 19, only a portion of this chromosome, considerably less than half, *i. e.*, about eight nineteenths, could be concerned with sex-determination.

If a comparison of the sex chromosome in the genera of this family leads us to believe that the sex-determining portion in the genus *Tettigidea* is at most not greater than eight nineteenths of the total, in the case of the supernumerary accessory described in this "Study" we have evidence, it seems, which limits the size of this portion to a still greater degree, namely, between one fifth and one fourth the length of the chromosome. The reasons for concluding this are as follows: The presence of the chromosome in this particular animal has not produced a female; hence it must lack the part concerned with sex determination. Bridges ('16), in his splendid work upon nondisjunction of pairing sex chromosomes in *Drosophila amphilophila*, has shown that sex determination may be excluded from one portion of the X-chromosome at least, and therefore limited to a part of it. He found that a small portion of the X-chromosome in the region which carries the genes for "barring of the eye" and "forked condition of the bristles" became nonexistent genetically (pp. 150, 151). Females could exist with one such deficient X-chromosome. The sons of such heterozygous females were only one-half as numerous as the daughters, and did not possess the deficiency. The evidence warranted the conclusion that males could not exist with such

a deficient chromosome, Bridges' discovery has demonstrated, in the first place, that deficiencies may occur in X-chromosomes; in the second place, that the sex differentiators are limited to a part of the X-chromosome, for they did not occur in that portion as least of the chromosome which has to do with the above genes and which lies between the loci of the genes for "rudimentary wing" and "fused." Now if such be the case in *Drosophila,* then in *Tettigidea* we are justified in concluding that the sex determinants may likewise be limited to a portion of the chromosome, and since the animal which has here been described as possessing one normal and one short X is a male instead of a female, it seems safe to conclude that possibly the missing portion of this chromosome contains the determiners for sex, and further that in the genus *Tettigidea* at least these determiners lie near one end, probably the distal end, of the chromosome.

TIME OF APPEARANCE OF THE LONGITUDINAL SPLIT IN SOMATIC CHROMOSOMES

This discussion can not be closed without reference to the evidence afforded in figures 2 to 5 upon the question of the time at which division of the chromosomes in somatic mitoses takes place. In figures 2 and 3, late prophases of cells from the follicular wall, any portion of a chromosome which happens to run at all vertically shows distinctly in cross-section a secondary split at right angles to the very wide and apparent primary split. In figure 3, at the arrow point, such a portion of chromosome No. 4 is drawn. Most of the chromosomes here show the same. These cells have not yet entered upon the metaphase stage of division. Division, when it comes, will take place in the plane of the very apparent primary split. The secondary split here present can only be for the next again metaphase. This is shown much more conclusively in anaphases (figs. 4 and 5) from the same tissues. Here it is certain that division along the primary plane has taken place. The daughter chromosomes in traveling to the poles of the spindle show clearly the secondary split (fig. 5). It must be remembered that these chromosomes are entering upon the telophase stage of division, and go from that to the "resting" condition of the cell. Such a split is likely the forerunner of

the split which is most apparent in the prophase figures 2 and 3.

This is not the first time that such a phenomenon has been described. Dehorne (1911) found the same to occur in the somatic mitoses of *Salamandra.* In addition, I have reason to believe that this phenomenon occurs in the chromosomes of the first spermatocyte of the *Tettigidæ,* while they are yet in the daughter-cell stage resulting from the last spermatogonial division. There it seems that the chromosomes, before entering upon the stages of side-to-side pairing in synapsis, are in reality definitely split along a longitudinal plane. Pairing takes place evidently between members that are already made up of two strands, and of course the four-part tetrad results.

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EXPLANATION OF PLATES I, II, AND III.

Drawings were made by aid of a camera lucida and are here reproduced at 2600 diameters. The pairs of autosomes are numbered, according to size, from 1 to 6. The normal "accessory" chromosome is numbered *5x*. The numeral *5* indicates that it ranks between the fourth and fifth autosome in size. *S* designates the deficient supernumerary "accessory" (?) chromosome.

FIGS. 1 to 5. Divisions in somatic cells each showing 14 choromosomes.

FIG. 1. Fat body cell. No. 5's are foreshortened.

FIG. 2. Cell from the follicular wall of the testis. Each large cromosome shows at the proximal end a peculiar somewhat knoblike portion, which seems to be less deeply stained. The chromosomes are woolly. The longitudinal split marked.

FIG. 3. Cell from follicle wall. Follicle itself was full of spermatozoa. Chromosome No. 5 is foreshortened. Each choromosome in figures 2 and 3 is split twice longitudinally. This may be seen by focusing on parts of chromosomes running vertically. See cross-section of No. 4 at arrow point.

FIG. 4. One of the daughter cells, in a late anaphase or telophase of a follicular cell. Distal ends of these chromosomes show the secondary split. That which takes place at the division which follows the resting stage into which this cell is about to pass.

FIG. 5. Cross-sectional view of a daughter group of chromosomes in the anaphase stage similar to figure 5. Chromosomes very long. The secondary split is quite visible. This cell will soon pass into the resting stage. Cell taken from wall in region of the neck of the follicle.

FIG. 6. Spermatogonium in metaphase stage of division. Fourteen chromosomes.

FIG. 7. Similar spermatogonium from another follicle.

FIGS. 8 to 21. Stages of first spermatocytes from early synapsis to division.

FIG. 8. "Sheaf stage," corresponding possibly to the "bouquet" stage of other authors. The numbers of each of the six pairs of autosomes are in parasynapsis at one end, probably distal, where six winding threads may be counted. The normal accessory chromosome (*5x*) and its deficient

mate (*s*) lie to one side of the nucleus coiled in corkscrew fashion, the spiral turning toward the right. Both point to what is probably the distal end of the cell.

FIGS. 9*a*, 9*b*. No. *5x* and *s* pairing in synapsis stages slightly later than figure 8.

FIGS. 10*a*, 10*b*. Similar stages. Each accessory shows a longitudinal split.

FIGS. 11*a*, 11*b*, 11*c*. Similar stages; all taken from one cyst. Accessory chromosomes usually lie near together, but may lie on opposite sides of the nucleus. Inequality of the two is apparent.

FIGS. 12, 13. Fine spireme stages following the bouquet stage. The accessory and its supernumerary mate may lie close together or on opposite sides of the nucleus. Both always lie on the nuclear membrane.

FIGS. 14*a* and 14*b*. Cell from two sections. Early prophase. Six pairs of autosomes form tetrads. The normal *5x* accessory and its mate near by. Note shortness of the supernumerary. Both are split.

FIGS. 15*a*, 15*b*, 15*c*. Three similar stages from other cells of the cyst. Both chromosomes split.

FIG. 16. Similar stage; complete cell. Chromosome No. 6 moved outward.

FIGS. 17 to 21. Division of first spermatocyte. Supernumerary going either with the accessory or to the opposite pole. In 65 to 75 per cent of the cases it lay near the accessory, but might not (figs. 20, 21). All other chromosomes of normal size and dividing normally. Chromosome No. 5 slightly displaced to right in figure 17.

FIGS. 22 to 25. Second spermatocyte division, polar view, showing six, seven and eight chromosomes, depending upon whether No. *5x* and *s* were absent or present, either one at a time or both.

FIGS. 26, 27. Second spermatocyte division, lateral views of the spindle, showing that all chromosomes divide. Six chromosomes in one, the *5x* and the *s* chromosome absent; eight in the other, both the *5x* and the *s* chromosome present.

PLATE I.

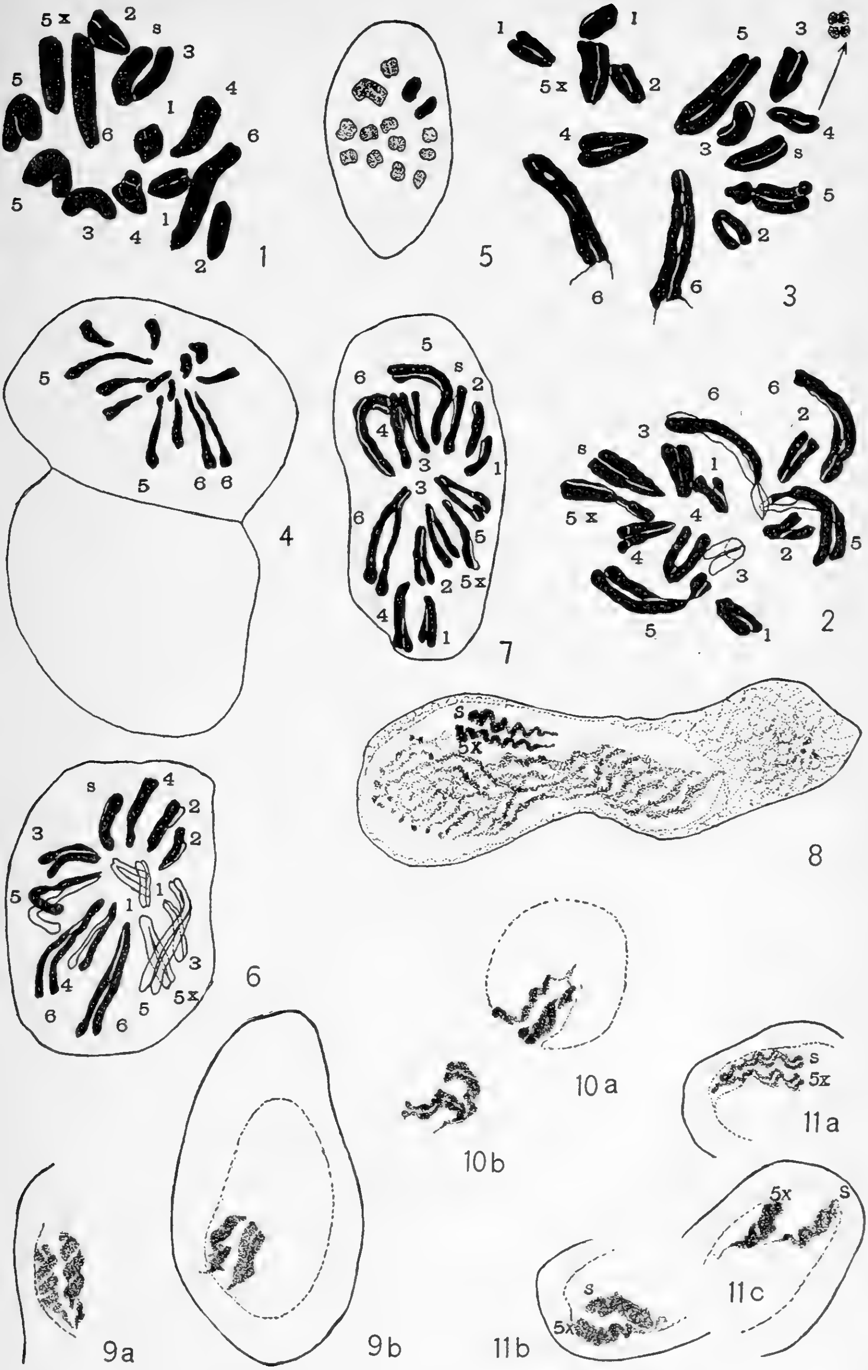
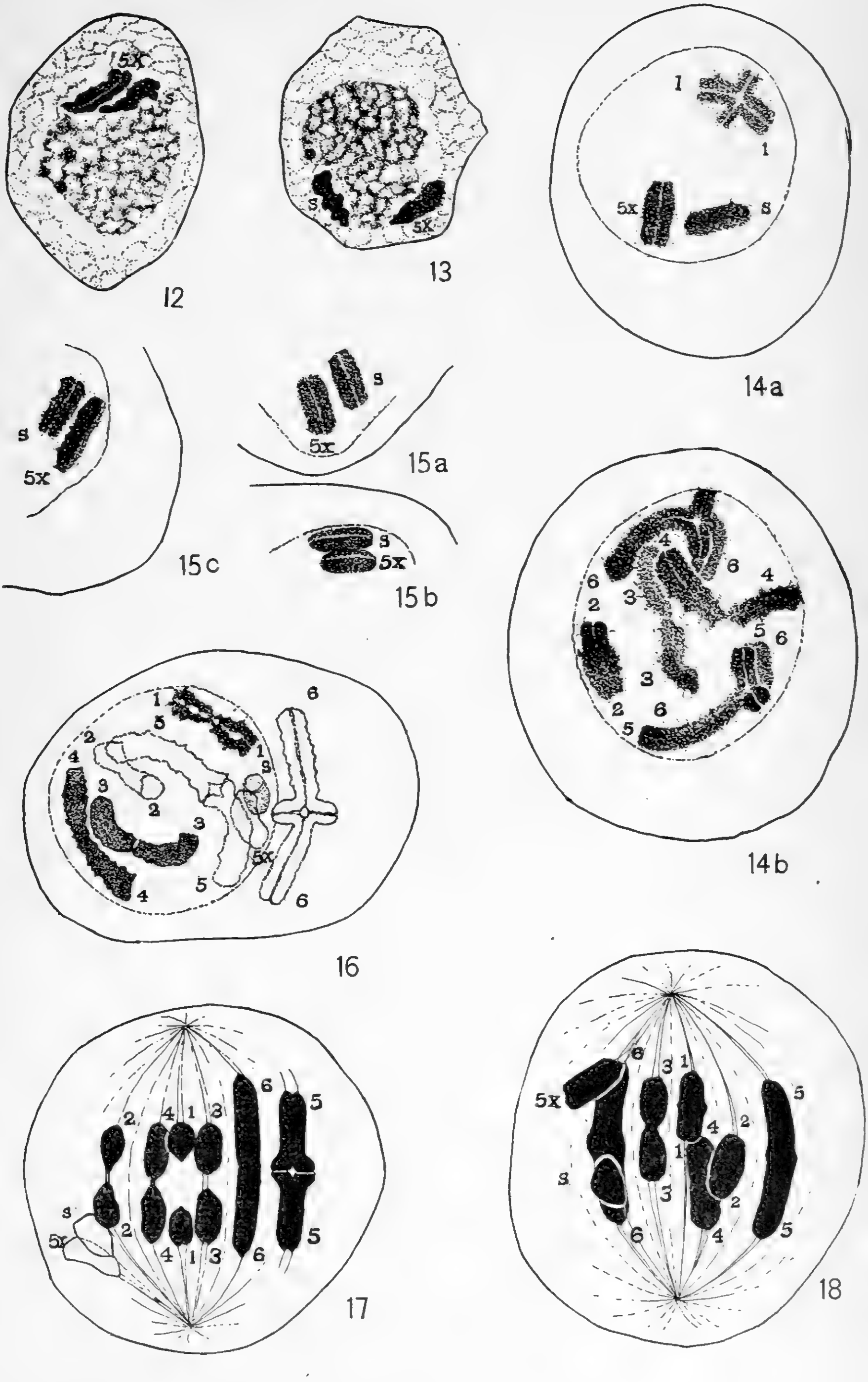
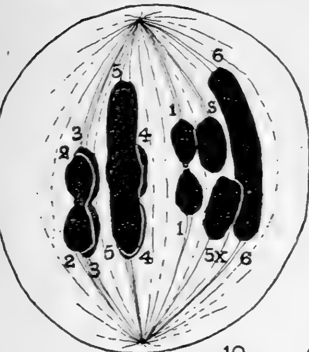


PLATE II.





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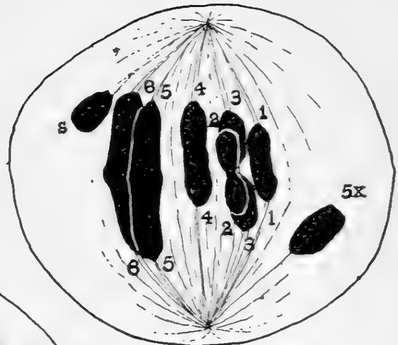

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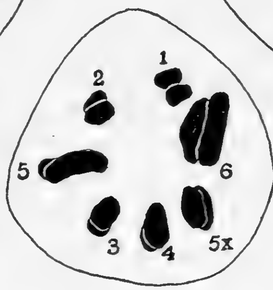

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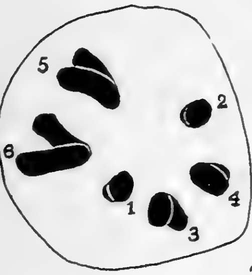

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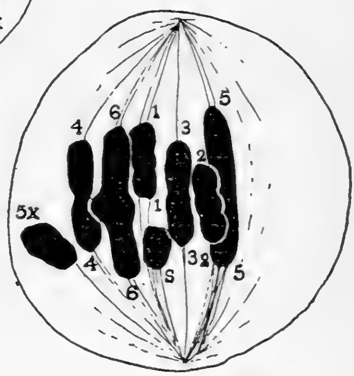

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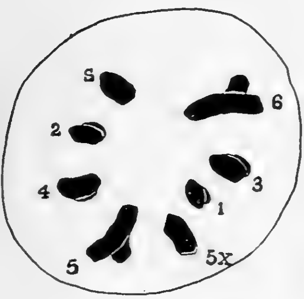

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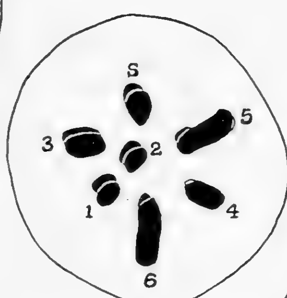

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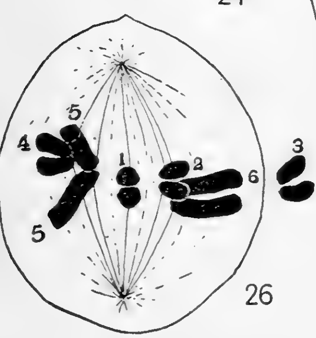

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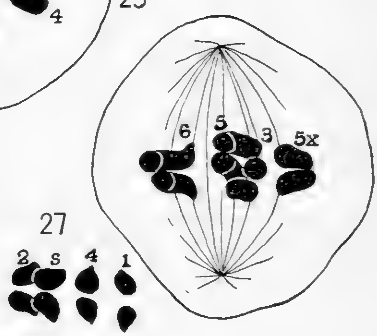

27

THE
KANSAS UNIVERSITY SCIENCE BULLETIN.

VOL. X, NO. 15—JANUARY, 1917.

(Whole Series, Vol. XX, No. 15.)

CONTENTS:

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THE KANSAS UNIVERSITY
SCIENCE BULLETIN.

VOL. X, NO. 15.] JANUARY, 1917. [WHOLE SERIES VOL. XX, NO. 15

A Mule and a Horse as Twins, and the Inheritance of Twinning.

W. REES BREBNER ROBERTSON,
University of Kansas.

THIS occurred on the farm of George E. Loy, of Barnard, Kan., June 9, 1913. On hearing of the case, in March, 1916, I looked it up and found, from the testimony of Mr. Loy and his family and neighbors, and that of the photographers who took the pictures and from my own observation, that the following are the facts concerned.

In 1912, the dam (III_9), just ten minutes before being bred to the ass stallion (III_7), had been bred to a young three-year-old horse stallion (III_6), which was being used as a part of the technique sometimes thought to be necessary in securing the fecundation of the female horse by the male ass. In such cases fertilization is expected from the second sire. In this instance, however, there resulted twins, one of which was a male horse, the other a female mule.

The case in itself was of sufficient interest, fortunately, to be photographed at the time by the local photographer, who sold the pictures (fig. 1) at fifteen cents apiece. Photographs were also taken later by the district school teacher (figs. 2, 3 and 5). Photographs 4 and 6 were taken by myself. Unfortunately, the mare (III_9) had died of old age during the wintertime preceding my visit, and the horse foal (IV_{10}) had died of exposure and poor feed the winter of 1914-'15 at eighteen months of age. But in spite of these discouragements, the data given by Mr. Loy and his children and by his neighbors checked up in every way so well with the evidence afforded by the photographers, and with what I have been able to observe myself, that it seems worth while to put the case on record.

On investigating the history of the mare I found that in the nine times she had produced foals she had given birth to twins (mules) on two other occasions, the fifth and ninth times (see plate I). In addition, her second foal (IV_3) had given birth to twins (horses), and also her own half sister (III_{10}) had produced twins, though the latter came too soon, being "slipped" at nine months gestation. Evidently there must have been present in the family the trait of twinning handed down from mother to daughter, and through three generations, starting with the Oregon "herd" mare.

That this twinning is of the dizygotic sort is proven by the differing colors and markings in all of the cases, and in two cases by differing sexes. In the first pair (IV_6 and IV_7) both were males; but one was black, the other brown. The black one lived only two days. In the second case occurred the mule and horse pair (IV_{10} and IV_{11}), which certainly must have been dizygotic. They differed in sex and in marking, though both were bay, but one a light bay (mule), the other darker bay (horse). In marking, the mule had a small crescent-like white blaze to the right of the center of the forehead (fig. 4). The horse was of uniform bay color with black mane, tail and feet.

In the third case (IV_{12} and IV_{13}) the twins were mules of different sex and marked differently, the female (IV_{13}, figs. 5 and 6) having a white spot in the forehead and in general color darker, with less of the light tan color characteristic of mules about the muzzle and under-barrel parts, while the male had no white markings, was generally lighter in color, and had, as the photos will show, more of the light tan color about the muzzle and ventral parts.

In the fourth case (IV_{14} and IV_{15}), in which twins were produced by a half sister (III_{10}) of the mare III_9, the foals were aborted at between 8 and 9 months gestation. The sexes, colors, etc., were not recorded.

The fifth case (V_1 and V_2 was a pair of horse twins, both of the same sex but differing in color and markings, from the daughter (IV_3) of III_9. They did not live to maturity.. One was a solid bay like the mother IV_3 and her sire III_1, while the other was sorrel with a "bald" white face and white feet, similar to the grand dam III_9 and the great grand dam (Oregon mare) II_4, and also to IV_1 (figs. 3 and 4), a full brother to the dam IV_3.

As the pedigree (plate I) will show, the mare was heterozygous for the presence of the bay factor, since her sire was black and her dam had the bay variation of chestnut, known (Castle's "Genetics and Eugenics") as sorrel. This probably gave her the ability to throw the black and brown coats of her first twin mules (IV_6 and IV_7) and also probably the darker and lighter brown coats of her third twin mules (IV_{12} and IV_{13}). That she carried the bay factor is certain from the fact that by a black horse stallion (III_6) she produced a solid bay colt (IV_{10}). Her daughter was probably heterozygous for black, which gave her, when bred to a sorrel sire (IV_2), the ability to throw in her twins one a sorrel, the other a bay like herself. This daughter must likewise have been heterozygous for spotting, *i. e.*, assuming spotting recessive. She herself was solid bay, but her mother (III_9) had white face and white points and one of her twin colts was similarly marked. These foals did not live to maturity.

By way of summary, these facts, then, show that in all probability each case of twinning in this family is one of the dizygotic type, due to the simultaneous, or nearly so, fertilization of two distinctly separate unlike ova by two unlike spermatoza. Of the four cases where observations were made, this is shown in two by differing sexes and at the same time differing general coat color and widely differing markings; in the two remaining cases by differing general coat color, black and sorrel or black and brown, and at the same time differing spotting with white. In addition, one of the former cases, where the sex of the pair is different, one foal is a mule and the other a horse.

A second conclusion is that in these cases we have evidence of the inheritance of the tendency to produce heterologous twins through three generations, transmitted evidently from the bald-faced sorrel Oregon mare (II_4), since two of her daughters (III_9 and III_{10}), by different sires, possessed the trait.

Likewise, it is probably to be concluded that in order to be the producer of such twins, the dam herself need not have been a twin, since neither III_9, III_{10} nor IV_3, all of which produced twins, were themselves twins. It must not be forgotten, however, that possibly the twin in each of these may have been formed but failed to develop.

In the case of the mule and horse twins, it might be supposed that the presence of a mule fœtus might in some way affect the development of a horse fœtus, and accordingly some abnormal characters appear in the horse (Lillie, '17). So far as I can see, no such characters are present. From the photographs that were taken (figs. 1-3), one can not detect mule characters. In figure 3 the hair is long, due likely to winter conditions. The photos of the mule show it likewise to be a normal animal.

The present occurrence of a mule and a horse as twins is probably what might be termed a case of superfecundation rather than superfœtation, since fertilization of both eggs could have taken place only at one period of heat. We have reason to think this from the fact that only one breeding to each sire occurred, and these breedings at a ten-minute interval. Mumford, in his text "The Breeding of Animals," gives seven examples of what he terms superfœtation. Six of these resulted in twin colts, one of which was a mule, the other a horse; but they resulted from fecundation at a second or later period of heat. One of the colts, accordingly, was usually smaller or less well developed than the other. In two of these cases both died at birth or soon after; in one case he does not say; in two cases one twin only died; while in one case (his plate II) both evidently lived. From the number of cases cited by Mumford, it may be seen that the occurrence of mule and horse twins is not such a rare phenomenon as one might expect. The facts in the case here presented and in the other cases probably indicate that such twins may be produced, not only by fertilization during pregnancy at a recurring period of heat, as Mumford's cases seem to be, but also as a result of the appearance of two ova in the uterus at once.

Newman, in his book "The Biology of Twins," p. 95, says: "At the present time, I have no reliable evidence of twinning in horses, but it is highly probable that this group offers no exception to the general rule that all mammals normally producing but a single offspring at a birth may have twins." The present case and those of Mumford, I believe, are now good evidence of twinning in the horse, and twinning in the case here described is shown to be of a hereditary nature.

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LILLIE, F. R. 1917. The Freemartin; A Study of the Sex Hormones in the Fœtal Life of Cattle. Journal Exp. Zool., vol. 23, No. 2.

MUMFORD, F. B. 1917. The Breeding of Animals. New York, The Macmillan Co.

NEWMAN, H. H. 1917. The Biology of Twins (Mammals). University of Chicago Press.

EXPLANATION OF PLATES.

PLATE I.

I_1. Black percheron stallion.

I_2. Black mare.

I_3. Full blood Arabian stallion; spotted over hips.

I_4. Wild pony mare from herd; color was black with large white spots.

II_1. McDuff, a black percheron stallion. Service charges, $25.

II_2. Black mare.

II_3. Arabian stallion; white, with some black spots.

II_4. Oregon mare, branded; color, sorrel; had white points from knees and hocks down, and a blaze in face.

III_1. Horse stallion; dark bay.

III_2. Ass stallion.

III_3. Ass stallion; black.

III_4. Ass stallion.

III_5. Ass stallion.

III_6. Horse stallion; black. Not related to III_9. Used to tease before breeding to ass stallion. Was two years old, coming three, at the time.

III_7. Ass stallion, "Mammoth" breed; gray. Owned by farmer W. T. Watson of Barnard, Kan. Used ten minutes after III_6.

III_8. Ass stallion.

III_9. Sorrel mare with white face and white points. (See figures 1, 2 and 3.) Face spot slightly to right. Foaled 1892. Mother of the mule twins, IV_6, IV_7; the horse-mule twins, IV_{10}, IV_{11}; and IV_{12}, IV_{13}. Died winter of 1915-'16.

III_{10}. Half sister to III_9, dam of twins IV_{14} and IV_{15}. Was owned by Mr. Loy's mother.

III_{11}. Horse stallion.

IV_1. Horse (gelding), sorrel. Foaled 1899. Markings and color (see fig. 4) same as mother III_9.

IV_2. Horse stallion; sorrel.

IV_3. Mare; solid bay. Foaled 1901. Mother of twins V_1 and V_2.

IV_4. Horse (gelding); solid bay. Foaled 1902.

IV_5. Mule (male).

IV_6, IV_7. Pair of male mule twins; one black, one brown. Black one died 48 hours after birth. "Its bowels did n't work. Veterinary gave it oil; then it scoured to death."

IV_8. Mule (female).

IV_9. Mule (female).

IV_{10}. Horse (male); bay with no spotting. (See figs. 1, 2 and 3.) Twin to mule IV_{11}. Normal. Lived into the second year, probably eighteen months. "Died of natural causes; poor feed and exposure in second winter (1914-'15."

IV_{11}. Mule (female). Twin to horse IV_{10}. Solid light bay; slight blaze to right of center of face. Normal strong mule. (See figs. 1, 2 and 4.)

IV_{12}. Mule (male); bay or brown. Twin to IV_{13}. No blaze on forehead; slightly lighter in color, and with lighter muzzle and under parts than its twin mate. (See figs. 5 and 6.)

IV_{13}. Mule (female); bay or brown. Twin to IV_{12}. Blaze on forehead; general color slightly darker, and muzzle and underparts slightly darker than twin mate. (See figs. 5 and 6.)

IV_{14}, IV_{15}. Pair of horse twins. Sex unrecorded; foaled too soon ("slipped") by half sister to III_9, at between eight and nine months of gestation.

V_1. Horse (male). Twin to V_2. Sorrel with bald face and white points like grand dam III_9. Did not live to maturity.

V_2. Horse (male). Twin to V_1. Solid bay. Did not live to maturity.

PLATES II, III AND IV.

FIG. 1. Photograph of mare III_9 and her horse-and-mule twins (IV_{10} and IV_{11}) at three days after birth, taken by a local photographer. Persons photographed are sons of the owner.

FIG. 2. Photograph of mare III_9 and her horse-and-mule twins, taken by the local school teacher in winter of 1914-'15.

FIG. 3. Photograph of mare III_9 and the horse colt twin, taken at same time by same party at closer range.

FIG. 4. The mule twin IV_{11}, in harness at thirty months of age. The horse IV_1 is the first colt of the mare III_9. Photo by the author, March, 1916.

FIG. 5. Third pair of twins (mules), IV_{12} and IV_{13}, at five days of age. Taken summer of 1915.

FIG. 6. Same as fig. 5, but lateral view. Photo by author, March, 1916.

PLATE I.

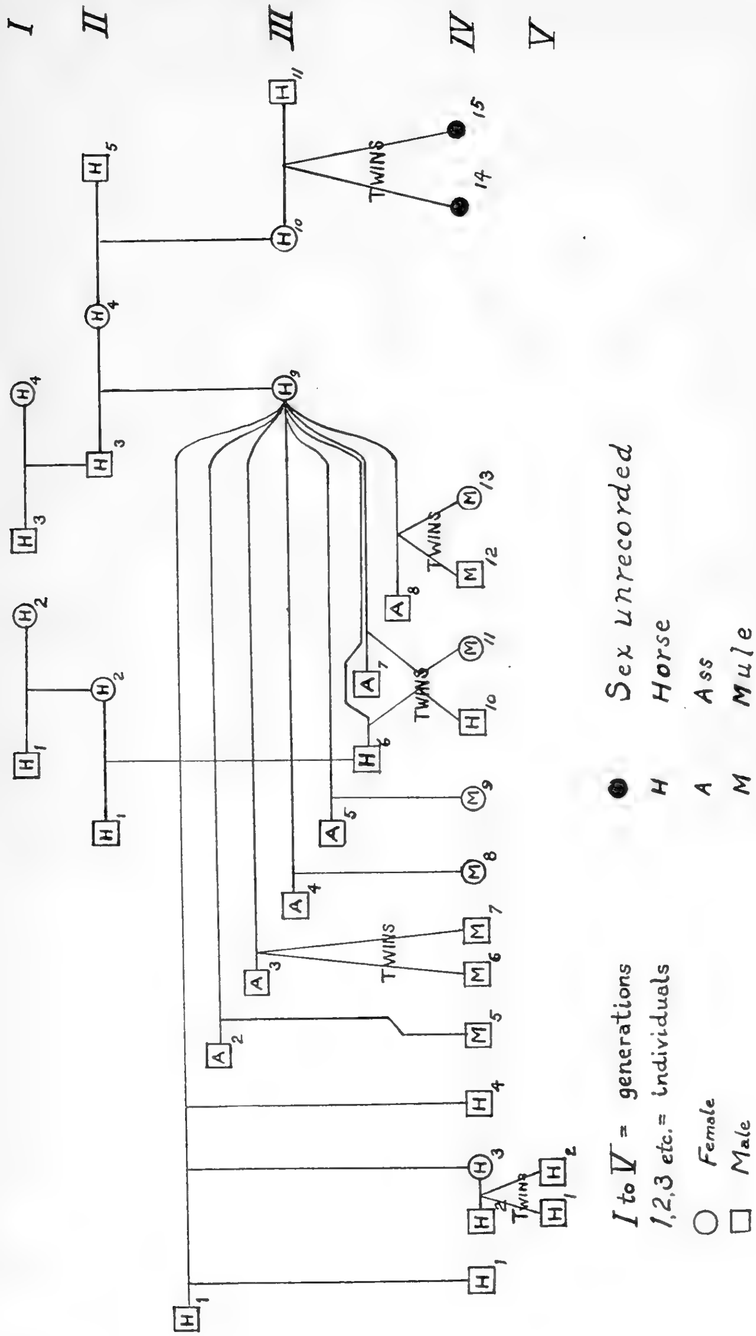

I
II
III
IV
V
TWINS
I to V = generations
1,2,3 etc. = individuals
Female
Male
Sex unrecorded
H Horse
A Ass
M Mule

PLATE II.

III 9 & IV 10 & 11.

Fig 1.

III 9 & IV 10 & 11.

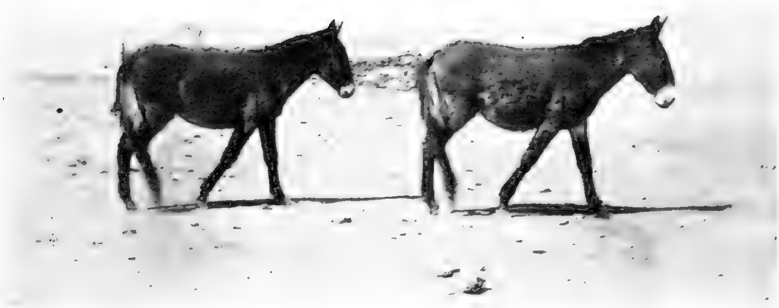
Fig 2

III_9 IV_{10} Fig 3

IV_{11} IV_1 Fig 4

IV 12 & 13

Fig 5



IV 13

IV 12

Fig 6

Publications of the University of Kansas.

The following publications of the University of Kansas are offered for sale at the prices named below, or in exchange for other publications of like character and of equal value. Separates of all articles in the *Science Bulletin,* beginning with volume V, No. 20, except volume VII, Nos. 1, 2, 16, may be obtained by exchange or purchase. The price varies with the number of pages.

KANSAS UNIVERSITY QUARTERLY.

Volume I. No. 1, supply large; price, 50 cents. Nos. 2 and 3, supply exhausted. No. 4, supply small; price, 75 cents.
" II. Supply exhausted.
" III. Nos. 1 and 2, supply exhausted. No. 3, supply small; price, 75 cents. No. 4, supply small; price, 50 cents.
" IV. No. 1, supply small; price, 50 cents. No. 2, supply small; price, 75 cents. Nos. 3 and 4, supply exhausted.
" V. Supply exhausted.
" VI, A. Supply exhausted.
" VI, B. Nos. 1, 2, 3, and 4, supply large; price per number, 50 cents; price per volume, $2.
" VII, A. Supply exhausted.
" VII, B. Nos. 1 and 2 (double number), 3, and 4, supply large; price per number, 50 cents; price per volume, $2.
" VIII, A. Nos. 1, 2, 3, and 4, supply large; price per number, 50 cents; price per volume, $2.
" VIII, B. No. 1, supply small; price, 50 cents. Publication suspended.
" IX, A. Nos. 1, 2, 3, and 4, supply large; price per number, 50 cents; per volume, $2.
" X, A. Nos. 1, 2, 3, and 4, supply large; price per number, 50 cents; per volume, $2.

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Price, $3 per volume; supply large.

Volume I. Nos. 1 to 12.
" II. Nos. 1 to 15.
" III. Nos. 1 to 10.
" IV. Nos. 1 to 20.
" V. Nos. 1 to 21.
Volume VI. Nos. 1 to 7.
" VII. Nos. 1 to 17.
" VIII. Nos. 1 to 10.
" IX. Nos. 1 to 21.

UNIVERSITY GEOLOGICAL SURVEY OF KANSAS.

Volume I, 1896. General Stratigraphy of Eastern Kansas; exhausted.
" II, 1897. General Geology of Western Kansas; exhausted.
" III, 1898. Special Report on Coal; weight, 4 pounds.
" IV, 1898. Upper Cretaceous Paleontology; exhausted.
" V, 1899. Gypsum and Gypsum Cement Plasters; weight, 2 pounds.
" VI, 1900. Carboniferous Invertebrates and Cretaceous Fishes; weight, 4 pounds.
" VII, 1902. Special Report on Mineral Waters; weight, 3 pounds.
" VIII, 1904. Special Report on Lead and Zinc; weight, 4 pounds.
" IX, 1909. Special Report on Oil and Gas; exhausted.

Bulletin 1, 1913. Special Report on Well Waters in Kansas; weight, 1 pound.
" 2, 1915. Crystalline Rocks in Kansas; weight, 1 pound.

MINERAL RESOURCES OF KANSAS.

Report for 1897, 1898, 1900-'01, 1902; exhausted.
Report for 1899, 1903; postage, 4 cents each.

The reports and bulletins of the University Geological Survey of Kansas and the reports on the Mineral Resources of Kansas are for free distribution on receipt of the proper postage, or may be sent by express, charges collect. Where weights are given consult your postmaster for parcel-post rates. Applications should be made to the State Geologist.

BULLETINS OF THE DEPARTMENT OF ENTOMOLOGY.

Scale Insects Injurious to Orchards; supply large. Postage, 2 cents.
The More Injurious Grasshoppers of Kansas; supply large. Postage, 2 cents.
Grasshopper Control in the Southern Division of Kansas. Postage, 2 cents.
The Green Bug.
Circular 4. Formulas for Destroying Injurious Insects and Plant Diseases.

Applications should be made to the State Entomologist, University of Kansas.

THE KANSAS UNIVERSITY SCIENCE BULLETIN

DEVOTED TO THE PUBLICATION OF THE RESULTS OF RESEARCH
BY MEMBERS OF THE UNIVERSITY OF KANSAS

VOL. XI

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Lawrence, Kan.

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CONTENTS OF VOLUME XI.

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VOL. XXI. DECEMBER 1, 1919. No. 17.

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8-1669

NOTICE TO EXCHANGES.

The attention of learned societies and other institutions which exchange scientific publications with the University of Kansas is called to the list of publications of this University on the third and fourth pages of the cover of this issue.

Those marked "Supply exhausted" cannot be furnished at all; those marked "Supply small" cannot be furnished separately; those marked "Supply large" will gladly be furnished to any of our exchanges who may need them to complete their files.

Back numbers of the *Kansas University Quarterly* and *Geological Survey*, as far as possible, will be sent to those of our newer correspondents who are able and willing to reciprocate.

ANNOUNCEMENT.

The *Kansas University Science Bulletin* (continuation of the *Kansas University Quarterly*) is issued in parts at irregular intervals. One or more volumes, containing from 300 to 400 pages of reading-matter, with necessary illustrations, is issued each year. The subscription price is $3 per volume. Exchanges with other institutions and learned societies everywhere are solicited. All *exchanges* should be addressed to the LIBRARY OF THE UNIVERSITY OF KANSAS.

All communications should be addressed to

THE KANSAS UNIVERSITY SCIENCE BULLETIN,
LAWRENCE, KAN.

THE KANSAS UNIVERSITY SCIENCE BULLETIN

VOL. XI—DECEMBER, 1919.

(Whole Series, Vol. XXI, No. 17.)

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8-1669

KANSAS STATE PRINTING PLANT
IMRI ZUMWALT, STATE PRINTER
TOPEKA. 1920
8-1669

COLOR PLATE I.

FIG. 1. Filaments of Spirogyra before being fed upon by a Corixid.

FIG. 2. The same after being fed upon by the bug. Note the empty filaments.

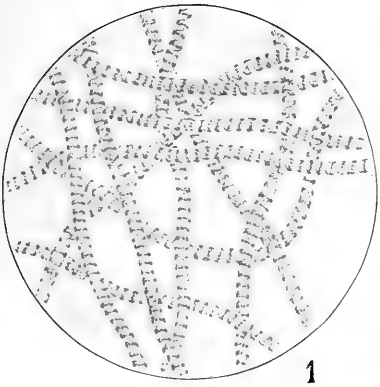
FIG. 3. An adult Corixid. (Water boatman.)

FIG. 4. A highly magnified portion of the Spirogyra shown in figure 2. Note the punctured and empty cells.

FIG. 5. The stomach contents of a small Corixid nymph after thirty minutes feeding on Spirogyra.

The above illustrations form conclusive proof of the herbivorous tastes of the water boatmen, and modify the frequent assertions of textbooks and serials that "All aquatic Hemiptera are predaceous."

The colored drawings on these three plates were made by Miss Ellen Edmonson.



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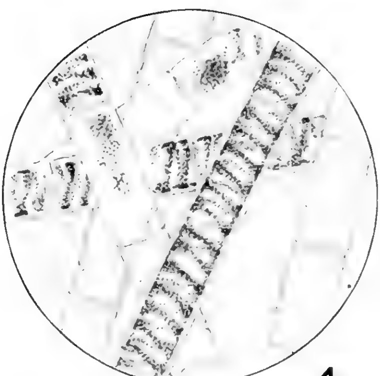

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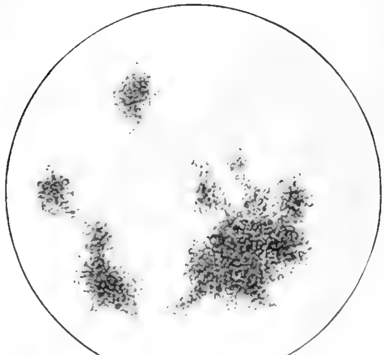

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COLOR PLATE II.

FIG. 1. *Notonecta undulata* Say. Our most common Kansas back swimmer. Magnification, 3½ times.

FIG. 2. *Plea striola* Fieb. The tiniest of the back swimmers and the pigmy of the water bugs. Magnification, 3.9 times.

FIG. 3. *Ranatra* or water scorpion. Lives in the trash of the pool and feeds upon luckless insects and even small fish. (This specimen identified in our Snow collections as *Ranatra americana.*) .7 natural size.

FIG. 4. *Buenoa margaretacea* Bueno. A slender back swimmer whose main food supply consists of the little Entomostraca crustacean creatures which form the food supply of practically all young fish. A form harmful to fish culture for this reason. Magnification, 3½ times.

FIG. 5. *Benacus griseus* Say. The large "electric-light bug" or "giant water bug." Destructive to fish up to three inches long at least. .7 natural size.

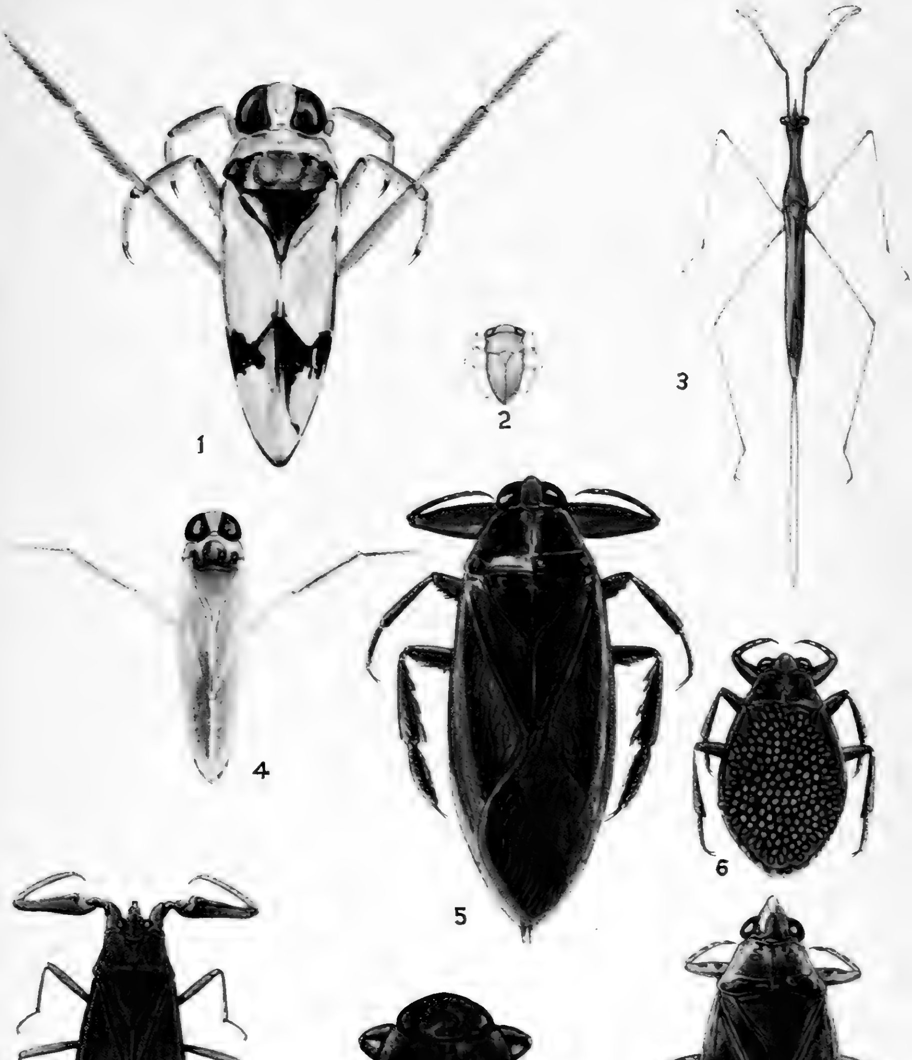
FIG. 6. *Abedus sp?* Male carrying the eggs which the female has glued to his back for safe keeping. .7 natural size.

FIG. 7. *Nepa apiculata* Uhl. A bug belonging to the same family as Ranatra, the Nepidæ. Found in mud and debris of shallow water. Magnification, 1⅔ times.

FIG. 8. *Pelocoris carolinensis* Bueno. A "creeping water bug" which lives in the tangled vegetation of fresh pools. Predatory in habits. One of the quickest of the water bugs to "sting" a careless collector. (Family Naucoridæ.) Magnification, 2.2 times.

FIG. 9. *Belostoma fluminea*um Say. A bug common in Kansas ponds. Feeds upon small water animals, including fish. The male with his back burdened with eggs is to be taken almost any time during summer. Magnification, 1⅘ times.

See p. 328.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COLOR PLATE III.

SEMIAQUATICS.

FIG. 1. *Hebrus concinnus* Uhl. A tiny bug dwelling on the shore and plant rafts. (Family Hebridæ.) Magnification, $12\frac{12}{17}$ times.

FIG. 2. *Hydrometra martini* Kirk. An exceedingly slender little bug living upon plant rafts. Called a "marsh treader." (Family Hydrometridæ, formerly Limnobatidæ.) Magnification, $3\frac{1}{2}$ times.

FIG. 3. *Rhagovelia obesa* Uhl. A dweller upon the fast running waters. (Family Veliidæ.) Magnification, $7\frac{9}{25}$ times.

FIG. 4. *Trepobates pictus* H. S. A beautiful surface strider. (Family Gerridæ.) Magnification, $7\frac{9}{25}$ times.

FIG. 5. *Gerris marginatus* Say. Our common water strider. Magnification, $3\frac{1}{2}$ times.

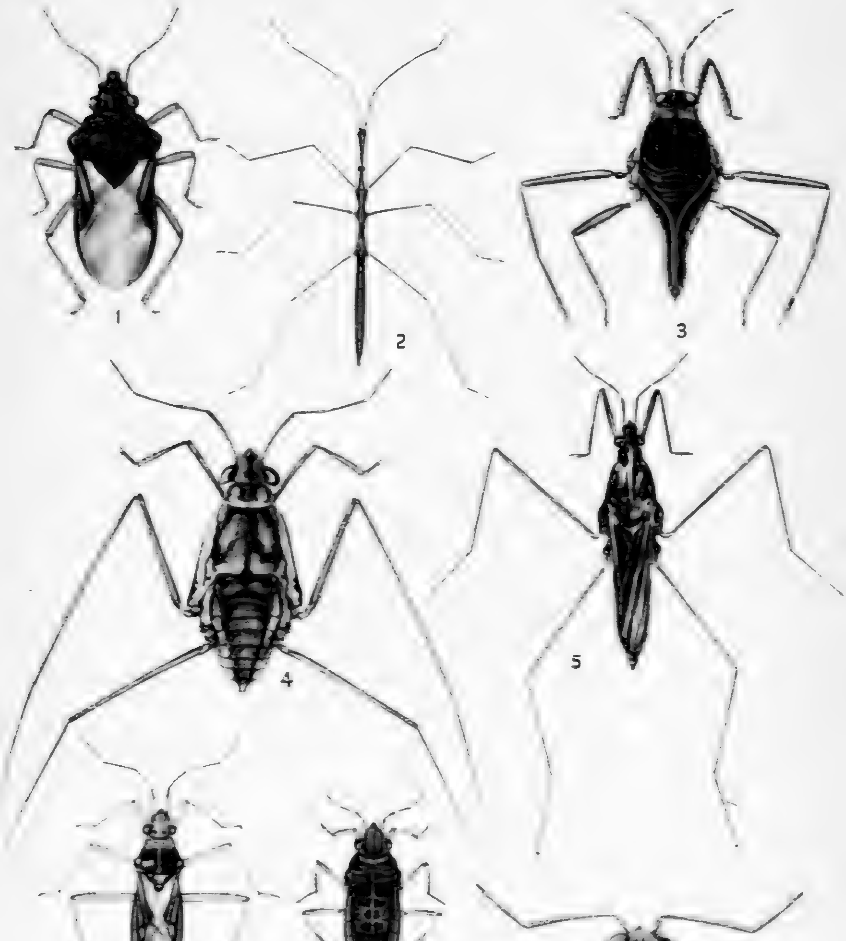
FIG. 6. *Mesovelia mulsanti* White. A small bug about the size of a chinch bug living in the same haunts as Hydrometra. (Family Mesoveliidæ.) Magnification, $7\frac{9}{25}$ times.

FIG. 7. *Microvelia borealis* Bueno. A tiny little bug found upon the water and about the banks of pools. This specimen is wingless, but many are winged. Magnification, $12\frac{12}{17}$ times.

FIG. 8. *Gelastocoris, species new?* The toad bug at home on the sandy shores of our streams (whether this bug is *G. oculatus, variegatus* or another is still in doubt. Some will say it is *variegatus*, being too well marked for *oculatus.*) Magnification, $3\frac{3}{17}$ times.

FIG. 9. *Ochterus americanus* Uhl. A shore bug intermediate between the toad bug and the Saldid shown in figure 10. The antennæ are intermediate in length between the long antennæ of the Soldidæ and the short antennæ of the toad bug. True aquatics have hidden antennæ. The toad bug has no objection to a swim in the water. The series from semiaquatic to true aquatic is shown by a study of figures 10, 9 and 8 of this plate and figure 8 of color plate II. Magnification, $6\frac{6}{17}$ times.

FIG. 10. *Pentacora signoreti* Guer. (Specimen determined in Snow collections.) Magnification, $6\frac{6}{17}$ times.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The Biology and Ecology of Aquatic and Semiaquatic Hemiptera*

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The writer wishes to acknowledge herewith his indebtedness to those who have aided him in his work.

First, to Dr. James G. Needham, of Cornell University, under whose direction these studies were made, he feels the deepest obligation and gratitude for the incentive and opportunity to investigate this neglected ecological group. His helpful, kindly suggestions and his broad limnological experience have ever been a source of inspiration to the writer in the preparation of this thesis.

To Prof. S. J. Hunter, of Kansas University, for so generously placing at his disposal time and equipment sufficient to complete these studies.

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TABLE OF CONTENTS.

FOREWORD.

It has been the aim of the writer to gather together, within the covers of one volume, the gist of all the information now available concerning the biology of the aquatic Hemiptera.

There was no intention in the beginning to include descriptions of species or other taxonomic matter. It was found, however, that there exists no work containing the descriptions of American genera and species.* These have been gathered together from various sources, some of them well nigh inaccessible, and are included in this paper to facilitate further study in the group.

The writer does not pretend to be an authority on systematic literature. He has followed Van Duzee's checklist and catalogue faithfully, digressing only in those cases where he has had the advice from taxonomists in the various families. Keys have been improvised from the literature, reduced to a synoptic plan, and tested upon all available material. This phase of the work, however, has been secondary and incidental to the main problem of extending the range of our knowledge of the ecology and biology of the water bugs. To this end the writer has searched the early literature for the first biological notes applied to the water bugs, has gleaned the periodicals, other serials and texts, and arranged the results in this paper under the families and genera as they now stand, adding his own contributions on the behavior, life history and ecological relations of these most interesting insects.

* Generic descriptions are often brief notes and specific descriptions are omitted for Belostomatidæ and Corixidæ, groups now undergoing careful revision.

INTRODUCTION.

In the summer of 1910 the writer was a member of a party which made an entomological survey of some fifteen counties in northwestern Kansas. The field work was under the immediate direction of F. X. Williams, while the collecting and listing of the Heteroptera was assigned to the writer. It was in this work that his interest was aroused in this group. Thus, when the opportunity came to work upon some limnological problem, under the direction of Dr. James G. Needham, it was very happily arranged that a study of the biology and ecology of the aquatic Hemiptera should be undertaken.

There are some thirteen families of Heteroptera that maintain a more or less intimate connection with the water. The Saldidæ, Gelastocoridæ, Ochteridæ and Hebridæ live upon the shore. The Hydrometridæ, Mesoveliidæ, and some of the Veliidæ (Microvelia, for instance) extend their range to the floating mats of green algæ and other plant rafts. The Gerridæ and some Veliidæ course the surface of the waters. While within the water dwell the Nepidæ and Belostomatidæ, which keep a more or less constant contact with the surface, and the Naucoridæ, Notonectidæ and Corixidæ that dart here and there through the water at will.

Bound together by the ecological factor of environment and relationship within an order, it has been the endeavor to treat, in the following pages, the habits, life histories, interrelations and outside associations of the water bugs in such a way that the result may be a finished thesis rather than a heterogeneous collection of notes. This is a difficult task from the very nature of the material treated. A glance at the table of contents will indicate the general arrangement of subject matter.

Survey of Families, Including a Synoptic Key to the Aquatic and Semiaquatic Hemiptera.

The water bugs that have been the object of these studies do not represent a close phylogenetic relationship within the Hemiptera. They belong to various categories, or "series," and are here treated together because they are members of a definite ecological factor, the water. In giving a brief survey of the relationships the writer follows Van Duzee's catalogue, who, in turn, follows Reuter, 1912. The arrangement and names are those of Van Duzee. Only the Heteroptera are discussed. It is true that certain aphids have been found living on the under surface of lily pads, but they have not been included. Arranged synoptically Van Duzee's classification follows. In the "Table to Heteroptera" the aquatics are shown in italic type.

A. Series *POLYNEURIA*.
  B. Supf. *Scutelleroideæ*.
    C. Phalanx *Pentatomiformes*.
      Scutelleridæ.
      Cydnidæ.
      Pentatomidæ.
  BB. Supf. *Coreoideæ*.
      Coreidæ.
AA. *PHLŒOBIOTICA*.
      Aradidæ.
AAA. *ONYCHIOPHORA*.
  B. Supf. *Lygæoideæ*.
    C. Phalanx Lygæiformes.
      Neididæ (Berytidæ).
      Lygæidæ.
    CC. Phalanx Pyrrhocoriformes.
      Pyrrhocoridæ.
AAAA. *ANONYCHIA*.
      Tingididæ.
  B. Supf. *Reduvioideæ*.
    C. Phalanx Enicocephaliformes.
      Enicocephalidæ.

AAAA. *ANONYCHIA—Concluded.*

CCC. Phalanx Hebriformes.
Hebridæ.
Mesoveliidæ.

CCCC. Phalanx Nabiformes.
Nabidæ.

BB. Supf. *Cimicoideæ.*

C. Phalanx Cimiciformes.
Cimicidæ (Acanthiidæ).
Anthocoridæ.
Termatophylidæ.

CC. Phalanx Miriformes.
Miridæ (Capsidæ).
Isometopidæ.

AAAAA. *TRICHOTELOCERA.*

B. Supf. *Dipsocoroideæ.*
Dipsocoridæ (Ceratocombidæ).
Schizopteridæ.

C. Phalanx Hydrometræformes.
Hydrometridæ (Limnobatidæ).

CC. Phalanx Gerriformes.
Gerridæ (Hydrobatidæ).
Veliidæ.

BB. Supf. *Leptopodoidea.*

C. Phalanx Leptopodiformes.
Saldidæ.

BBB. Supf. *Notonectoideæ.*

C. Phalanx Notonectæformes.
Notonectidæ.

CC. Phalanx Nepæformes.
Naucoridæ.
Nepidæ.
Belostomatidæ.

BBBB. Supf. *Ochteroideæ.*

C. Phalanx Ochteriformes.
Gelastocoridæ.
(Galgulidæ).
(Nerthridæ).
(Mononychidæ).
Ochteridæ (Pelogonidæ).

AAAAAA. *SANDALIORRHYNCHA.*

B. Supf. *Corixideæ.*
Corixidæ.

AAAAAAA. *AUCHENORHYNCHA.*

Cicadidæ.
Cercopidæ.
Membracidæ.
Cicadellidæ (Jassidæ).
Fulgoridæ.

AAAAAAAA. *STERNORHYNCHA.*

Chermidæ (Psyllidæ).
Coccidæ.
Aleurodidæ.
Aphididæ.

TABLE TO HETEROPTERA.

Series.	*Superfamily.*	*Phalynx.*	*Family.*
			Scutelleridæ
	Scutelleroideæ	Pentatomiformes	Cydnidæ
POLYNEURIA			Pentatomidæ
	Coreoideæ		Coreidæ
PHLOEOBIOTICA			Aradidæ
		Lygaeiformes	Neididæ (Berytidæ)
ONYCHIOPHORA	Lygaeoideæ		Lygaeidæ
		Pyrrhocoriformes	Pyrrhocoridæ
			Tingididæ
		Enicocephaliformes	Enicocephalidæ
		Reduviiformes	Phymatidæ
	Reduvioideæ		Reduviidæ
		Hebriformes	*Hebridæ*
ANONYCHIA			*Mesoveliidæ*
		Nabiformes	Nabidæ
			Cimicidæ (Acanthiidæ)
		Cimiformes	Anthocoridæ
	Cimicoideæ		Termatophylidæ
		Miriformes	Miridæ (Capsidæ)
			Isometopidæ
			Dipsocoridæ (Ceratocombidæ)
			Schizopteridæ
	Dipsocoroideæ	Hydsometraeformes	*Hydrometridæ* (Limnobatidæ)
		Gerriformes	*Gerridæ* (Hydrobatidæ)
			Veliidæ
	Leptopodoideæ	Leptopodiformes	*Saldidæ*
		Notonectaeformes	*Notonectidæ*
TRICHOTELOCERA	Notonectoidæ		*Naucoridæ*
		Nepaeformes	*Nepidæ*
			Belostomatidæ
			Gelastocoridæ
			(Galgulidæ)
	Ochteroideæ	Ochteriformes	(Nerthridæ)
			(Mononychidæ)
			Ochteridæ (Pelogomidæ)
SANDALIORRHYNCHA	Corixoideæ		*Corixidæ*

KEY TO HEMIPTERA.

(Aquatic and semiaquatic.)

A. Antennæ shorter than head.
  B. Ocelli present; semiaquatic.
    C. Antennæ exposed; front and middle legs similar. *Ochteridæ.*
    CC. Antennæ concealed; front legs raptorial, eyes protuberant. *Gelastocoridæ.*

A. Antennæ shorter than head—*concluded.*

BB. Ocelli absent; aquatic.

C. Hind tarsi with indistinct setiform claws. (Save *Plea,* which is less than 3 mm. long.)

D. Head overlapping thorax dorsally. Front tarsi 1-segmented, palæform. *Corixidæ.*

DD. Head inserted in thorax. Front tarsi normal. *Notonectidæ.*

CC. Hind tarsi with distinct claws.

D. Membrane of hemelytra reticulately veined.

E. Apical appendages of abdomen long and slender; tarsi 1-segmented. *Nepidæ.*

EE. Apical appendages of abdomen short and flat, retractile. Tarsi 2-segmented. *Belostomatidæ.*

DD. Membrane of hemelytra without veins. *Naucoridæ.*

AA. Antennæ as long or longer than head, exposed.

B. Head as long as entire thorax; both elongated. Length about 10 mm. *Hydrometridæ.*

BB. Head shorter than thorax, including scutellum.

C. Claws of at least the front tarsi distinctly anteapical, with terminal tarsal segment more or less cleft.

D. Hind femur extending much beyond apex of abdomen; intermediate and hind pairs of legs approximated, very distant from front pair. Beak 4-segmented. *Gerridæ.*

DD. Hind femur not extending much beyond apex of abdomen; intermediate pair of legs about equidistant from front and hind pairs (except in Rhagovelia). Beak 3-segmented. *Veliidæ.*

CC. Claws all apical, last segment entire.

D. Antennæ 5-segmented (save Merragata, which has 4). First and second segments of antennæ thicker than the others; clavus similar in texture to the membrane, which is without veins; head and thorax sulcate beneath. *Hebridæ.*

DD. Antennæ 4-segmented. Hemelytra not as above.

E. Membrane of wing without cells, or apterous. *Mesoveliidæ.*

EE. Membrane of wing with 4 or 5 long closed cells. *Saldidæ.*

Historical Sketch of the Biology of Aquatic and Semiaquatic Hemiptera.

The entomologist of to-day, who fails to review the works of the early writers, misses much that would add to his appreciation of the age and dignity of his science. The seventeenth century workers were acquainted with some of the wonderful transformations of insects. In the field of aquatic Hemiptera there were notes prior to 1600, but Aldrovandi, in his "Historium Natura de animalibus," 1618, gives us our first available notes on water bugs. No doubt observations had been made by scientific workers before him, for in Mouffet's "Insectorum theatrum," 1634, are figures of Notonecta, Nepa and Ranatra. When we recall that Mouffet's information probably came to him in the form of manuscripts handed down through the varying fortunes of time from the great Swiss naturalist, Conrad Gesner, who worked in the first half of the sixteenth century (born 1516, died 1578), we are justified in believing that some knowledge of the water bugs was early achieved.

In 1726 Marie Sybille Merian, a lady who was more artist than scientist, brought forth a "Dissertation sur la generation et les transformations des insectes de Surinam." In this she figures the rapaceous habit of a Belostomatid in feeding upon a frog!

Frisch (1727-28) brought out the first of a series of extended works that included those of Reaumur, Roesel, De Geer, Goeffrey, etc. He figured under most cumbersome names some of the water bugs. Since his plates are the first creditable ones to appear, those pertaining to water bugs are reproduced on plate IV.

It is unfortunate that Swammerdam's "Biblia naturæ" (1737-38) should bear a date later than Frisch, because the work was done some years before his death, which took place in 1680. It is in Swammerdam that we find an argument against spontaneous generation. He was speaking of water bugs. "These water scorpions live in the water all the day, out of which they rise about the dusk of the evening into the

air, and so, flying from place to place, often betake themselves in quest of food to other waters. This is always their course when the ditches in which they inhabit come to be dried up. This affords us a satisfactory reason for the great number of insects that immediately appear in the smallest collections of water, since they may very well get thither when it is dark, so that the opinion which ascribes to putrefaction, the power of forming insects, must by this instance of the water scorpion's nocturnal transmigration appear more and more frivolous and unnecessary."

Reaumur (1736) unfortunately did not write of water bugs, and Linne (1746-58) busied himself with setting in order our knowledge of natural history. Roesel (1746-1761) published four volumes, well illustrated, and in his work gives some attention to the water bugs. De Geer (1752) produced a seven-volume work "Memoirs pour servir a l'histoire des Insectes." A little later Geoffrey (1762) gave his "Histoire abrégée des Insectes." De Geer's "Abhandlungen zur Geschichte der Insekten," 1778, contains some splendid wood cuts, and in Vol. 3, considerable biological matter on water bugs. Oliver's work appeared in 1782. Fabricius must be mentioned in passing, because of his influence in the realm of the systematic. His "Entomologia systematica" came out in 1794, and his "Systema Rhyngotorum" in 1803. The first five years of the 19th century are memorable ones for students of the Hemiptera. Walchenaer, 1802, published "Faune parisienne, Insectes, ou histoire abregee des Insectes des environs de Paris, etc.," and herein gives biological data on the aquatics. Tigny, 1802, published a compilation and Latreille gave to the world his splendid set, "Histoire naturelle générale et particulière des Crustacés et des Insectes." Again in 1807 there appeared another of his works "Genera Crustaceorum et Insectorum secundum ordinen naturalem in familiar desposita inconibus exemplisque plurimis explicata." About this time Wolff and Rossias published less important works. Thus we find Fabricius, Latreille, Walchenaer, Tigny, and lesser workers producing much work from 1800 to 1805. Lamarck (1816) brought out another large set on insects and other invertebrates. He called his work "Histoire naturelle des animaux sans vertebres . . ." In volume 3 there are some splendid old matters concerning water bugs, notes on progression and feeding. As is often

the case, this same year (1816) marks the appearance of Savigny's "Memoires sur les Animaux sans vertebres." It is not, however, in the same class with Lamarck. The following year Leach (1817) published an important paper in the Trans. Linn. Soc. London, and in 1818 Fallen's "Monographia Cimicum Sueciæ" appeared. These are not biological in nature, but must be mentioned because of their important relation to the field. Eschscholtz in 1823, and Le Peletier and Serville in 1825 published works. Meneville (1829) treated water bugs in volume 13, giving colored plates of them in volume 14. Schummel (1832) and Laporte (1833) are responsible for a few notes, but a profound and splendid work by Dufour in 1833 marks this period as an important one. His paper, under the broad title "Recherches anatomiques et philosophiques sur les Hémiptères accompagnees de considerations relatives a l'historie naturelle et la classification des insectes," presented much new and interesting biological data. Two years later Burmeister's "Handbuch der Entomologie" appeared. And in 1836, just a century after Reaumur, we have Brulle's "Histoire Naturelle des Insectes." Volume IX treats of our bugs. Blanchard's set bears the same title and came out in 1840. 1843 is a date to be remembered by all students of the Hemiptera, for in that year Amyot and Serville set forth in their treatment of the Hemiptera a most thorough review of all earlier work (they omitted Roesel). After one has carefully combed through the early works for biological notes it is most satisfying to see how well these writers digested and set down the work of their predecessors.* Since their time there have been important contributions to the biology of aquatic Hemiptera. Many are the notes and short papers by various writers, but for extensive contributions we are indebted to a few. Uhler, in this country, stands as an early and a most interesting writer on the behavior and habits of this special group. Kirkaldy, in England, published in the "Entomologist," from 1896 to 1909, a series of articles under the title "Guide to the Study of British Water Bugs." This series should be read along with Uhler as the foundation material for any one taking up the study of water bugs. To these names we should add that of Bueno, who has published more life history studies than any other writer. His writings are most entertaining

* Glover has given us in his own handwriting something of the same thing in English.

and suggestive. He departs from the prosaic in setting forth the behavior of the bugs he has studied. Like Uhler, he takes the trouble to make you go with him to the aquarium or the pool and see the little details of the daily life of the bugs he depicts.

In the past few years we have had a number of texts relating to water life, but little that is original on water bugs. Wesenberg-Lund and Brocher stand out as most important foreign contributors to the general biology of the group with detailed studies upon single insects by Dogs, Wefelschied and Hagemann.

Much important work on morphology relates to the insect biology, but to enumerate the many truly important papers on mouth parts, genitalia, and the like, would bring us without the limits of this paper.

Ecologic and Economic Relations.

OUTLINE OF ECOLOGIC AND ECONOMIC RELATIONS.

I. ECOLOGY:
- A. Regions.
- B. Notes on a few streams and standing waters surveyed.
  - *a.* Western Kansas.
  - *b.* Eastern Kansas.
    1. Lake View.
    2. Haskell Pond.
    3. Griesa Pond.
    4. Smith Pond.
    5. Quarry pools. Rock Pool. Cattail Pool.
  - *c.* Central New York.
    1. Field Station.
    2. Bool's Backwater.
    3. Ringwood Hollow.
- C. Two pools and two seasons.
  1. A temporary pool.
  2. A permanent pool.
- D. Interrelations within the pool, a restricted environment.
  - *a.* Haunts and Habits.
  - *b.* Habitat Key.
  - *c.* Relation to other organisms.
    1. Parasitism.
    2. Oviposition in plant tissues and upon animals.
    3. Relation to other organisms largely a question of feeding habits.

II. ECONOMIC IMPORTANCE.

ECOLOGY.

REGIONS STUDIED.

Three distinct types of country with their attending water bodies have been surveyed in connection with these studies on the water bugs: Western Kansas, Eastern Kansas, and Central New York.

Western Kansas is a high, dry, level land. Its vast plains are little broken by the eroding forces of the water and the

vista is unmodified by timbered tracts. The rivers are but slender threads of silver, wending their way through wide strips of sand, margined by shallow banks. The lesser streams are little more than connected series of pools, which, if spring fed, may survive the drouths of summer. The meandering channels of these latter are mere ditches bordered by narrow meadows lower than the surrounding level and covered with a more luxuriant growth of grasses. The region, however, is not without interest for the student of aquatic Hemiptera. The sandy stretches by the river channel abound with toad bugs and Saldids, while the pools along river and stream course are populated by the true aquatics.

Eastern Kansas is more varied in its topography. There are stretches of upland plain, wooded slopes and rich alluvial flood plains. The rivers meander through wide valleys, dropping their never-ending burdens of silt in every stretch of slackened water, to add to the already obstructed channels. The waters of the region are typically muddy. The standing waters consist of oxbow lakes and artificial ponds. These depend upon the runoff of the land for maintenance. Now and then a clear spring-fed pool may be found in some stream near its source, but such a pool is by no means common. There is plenty of water for a study of those forms of aquatic life that thrive in muddy, quiet waters. The spring freshets give rise to numerous temporary pools that linger until the dry days of summer lap them up, and these present an interesting study of transient and indigenous populations that spring up, flourish for a time, and disappear with the passing of the waters.

Central New York presents a marked contrast to the foregoing. It is a region of great, rolling, wooded hills, with upland bogs and marshy meadows, spring-fed pools and sparkling brooks, deep ravines with water falls and rapids, and finally, narrow valleys with their scant flood plains and lake-confining basins. Here indeed is a wealth of water types. To one accustomed to collecting in the sluggish streams and artificial ponds in Kansas the environs of Ithaca, N. Y., afford a rare opportunity. Here, within easy reach of the city, are to be found all gradations from well-areated, rushing, tumbling waters of the brook to the dark, acrid, sluggish streams of the upland bog; from spring-fed pools to lake conditions.

Thus, of the three types studied, this last presents, by far,

the richest fauna for the student of inland waters. It would be interesting to note the characteristics of each pool or stream surveyed in the course of these studies, from west to east, but time and space will not permit. A few types are described here and in the body of the text and a few photographs presented to indicate the nature of the water bodies. See Plates I and II with attending legends.

NOTES ON A FEW STREAMS AND STANDING WATERS STUDIED.

Western Kansas.

Collections have been available from every county in the western half of Kansas, but only the thirteen counties north and west of Lane county have been surveyed by the writer. This region is drained by three rivers and their tributaries. The Republican river and its branches, Beaver, Sappa and Prairie Dog Creeks, cover Decatur, Rawline, Cheyenne, Sherman, and most of Thomas counties. The Solomon arises in Thomas county and passes through Sheridan, while the Smoky Hill drains Wallace, Greeley, Logan, Wichita, Scott and Gove counties.

Most of these streams are intermittent, often sinking into the sands of their channels during a dry spell. At the time collections were made near Russell Springs, in Logan county, the Smoky Hill river was a stream eighteen inches broad and from one-half to three inches deep on a bed of sand several rods wide. A few pools were found where water bugs could be collected. Several weeks later, when we were camped farther up the river in Wallace county, the stream had ceased to flow. The camp was set under a few willow trees on a sandy flat some distance from the channel and several feet higher than the normal water mark. This sandy stretch, close to the place where the water should have been, was splendid collecting for Toad bugs. There was no vegetation or other shelter to obstruct collecting. A few nights after arriving at this place a rain up-stream caused a great change. The entire flat, including our camping place was covered with water very shortly. We concluded, from this experience, that the vicissitudes of the inhabitants of the sandy stretches bordering western Kansas rivers must evidently be great—one hour upon dry sand and the next submerged beneath a seething torrent of water.

Such a catastrophe did not disturb the Gelastocorids, for they were out again as soon as the waters sufficiently receded. (Plate II shows a photograph of a western Kansas river.)

Eastern Kansas.

Collections were made in the pools and ponds about Lawrence. Lake View, the largest standing body of water available, is six miles from the city. This occupies an abandoned channel of the Kaw river, and is, in fact, an "oxbow" lake. This strip of water is perhaps 150 yards across and a mile long, fringed by willows along the sides and encroached upon at the ends by cattail, scouring rush and other plants. A thorough survey has never been made of this place.

Haskell Pond: An artificial pond covering perhaps half an acre. This pond has a muddy bottom and little vegetation. It is fed by the runoff of the land and by a little intermittent stream that has its origin in some springy ground in a mowland meadow above the pond. This stream, a mere ditch, overgrown by tall marsh grass, contains several water holes that have been good collecting for water bugs, especially for Belostoma.

Griesa Pond: A little dammed-up pool of very muddy water, in extent perhaps, three rods long and two broad. This is located in a five-acre lot and invaded by two or three cows in fly time. Since the bottom consists of deep, fine silt these visitations keep it ever turbid and filthy. It was in this pond that the Ramphocorixa and the egg-burdened crayfish were most abundant.

Smith Pond: Of the same type as above, but less muddy, being located in a pasture and so situated as to receive less silt. It is more than three times the size of the Griesa pool, and perhaps four feet in its deepest part. There are no seed plants growing in the pool. Unicellular algæ make its waters green in midsummer. Entomostraca became exceedingly abundant here one dry summer, and the pond was teeming with thousands of the back-swimmers of the genus Buenoa.

The Quarry Pools: Two temporary pools, occupying depressions where limestone had been quarried, were visited one season almost daily from earliest spring until they disappeared. The two pools were quite different. One named the Cattail pool was surrounded by cattail. Its waters were clear and

contained considerable growth of Spirogyra. One side was bordered with spike rush, *Eleocharis obtusa*. This little pool, a rod wide and perhaps three long, of clear, open water, proved the best collecting ground of any of those studied. *Hydrometra martini, Microvelia borealis, Mesovelia mulsanti* and *Gerris marginatus* patrolled the waters and floating rafts of algæ. *Arctocorixa alternata* and *Notonecta undulata* were dominant within the pool. Ostracods, the basis of the food supply for the young back-swimmers and for the smaller surface forms as well, were present in astonishing numbers. (See Plate I for photograph.) The other pool, called the Rock Pool was roughly a rod square and contained no vegetation save a margin of spike rush and sedge, the outermost procumbent stems of which floated upon the water and made footing for the Mesovelias that dwelt about the pool. The water soaked stems of this rush were, more than those of any other, employed by the Mesovelias in oviposition. This pool contained many Corixids but fewer back-swimmers than the Cattail Pool.

All of these pools, save the first, are within five minutes ride from the writer's residence, and were visited several times a week throughout the season.

Several other bodies of water, the Brick Plant ponds and Bismarck Grove pond, were surveyed frequently. These waters occupy several acres in extent, are devoid of vegetation, and afforded less satisfactory studies than the smaller pools. They are shown in the photographs, Plate I.

Central New York.

The principal waters studied were within easy reach from Cornell University. Since the true water bugs are seldom found in running waters, the frequent surveys were confined to the quiet waters.

The Field Station: This is located in the marshy meadows at the south end of Lake Cayuga. It is surrounded by a system of pools, some isolated, others connected by outlet to the lake. The isolated pools were newly made and contained few bugs, other than the back-swimmers. One pool, close by the station, was fed by a flowing well and its waters contained quantities of Elodea and other aquatic plants. This pool was open most of the time throughout the winter, and was ever a place to collect water bugs in great numbers. Four species of

Notonecta, the little Plea, and Corixids in both numbers and variety were here. Ranatra and Nepa, too, came into the catch often enough to call them plentiful. Of all the places the writer has ever collected, this pool in late fall and early winter has been the best collecting.

East of the Field Station there is a little stretch of water, connected with the Fall Creek outlet, in which there is a dense growth of water shamrock in summer. In midsummer the floating leaves of this plant make footing for the surface forms such as Mesovelias, Microvelias and Hebrids. In earliest spring the brown tangle of the stems of the previous year's growth harbored hundreds of *Notonecta variabilis.* These scattered to other regions for breeding purposes and were not abundant in June.

Bool's Backwater: A very few minutes brisk walk east of the Insectary at Cornell takes one about the border of the Beebe Lake and across a couple blocks of Forest Home to a steep bank overlooking a strip of land bordering an abandoned channel of Fall Creek. This old channel can be followed to its junction with Fall Creek at its upper end. Near this point arises the first of a series of clear pools which are fed by seepage from Fall Creek, by springs or by both, and which, in turn, overflow to form a little brook that trickles along over large water-worn stones covered by vast quantities of brown gelatinous growths of diatoms, to come finally to the quiet body of water filling the old channel for a considerable distance back from its union with Fall Creek, due to the damming of the latter a short way below. This is Bool's Backwater. Its waters are fresh but still, and great beds of Elodea and Chara occupy ever-increasing areas as the season advances. The bottom is somewhat muddy and the shallow margins deeply covered with a flocculent organic ooze, ideal food for the boatmen. And here, indeed, two species of Corixids were to be taken in countless numbers. Because of this fact and its accessibility, this place was chosen for daily observation and notes taken on these frequent visitations are elsewhere recorded.

Ringwood Hollow: A series of interesting pools and marshy meadows in Ringwood Hollow were visited at rather frequent intervals throughout the season. These were reached by a short ride on the train, followed by perhaps three miles of walking.

The area contains a pool in a springy pasture meadow, and Winterberry pool, a shallow bit of water overgrown with clumps of winterberry bush and encroached upon by procumbent moss-covered masses of the fallen trees of former days. This water in midsummer was solidly overgrown by duckweed, which made satisfactory collecting difficult Aside from a few Belostomatids this was not good collecting.

To the west of this pool are two others, nearly circular in outline, and occupying depressions doubtless made by tardy ice blocks, as the glaciers left the land. These are in a wooded tract and their bottoms are deeply strewn with leaves. They were good collecting for water bugs in early spring, but with the advancing season they were abandoned by the bugs for more favorable breeding places.

Occasional trips were made to Dwyers ponds and a splendid pool on Six Mile Creek, but with less of the regularity followed in surveying the others.

TWO POOLS AND TWO SEASONS.

Attempts have been made to follow very closely the advancements of the season in nature. To do this successfully certain pools have been selected and surveys recorded at frequent intervals. From the field notes in this connection one is impressed by the varying fortunes of the life in a pool during the course of the season. Some of the notes taken in connection with two studies are here given because they show the history of two pool types, one a temporary Kansas pool and the other a permanent body of water in New York state.

A Temporary Pool.

The pool described above as the Cattail pool was visited regularly from early March until July 28, 1916, when all the water had disappeared. This pool was visited November 20, 1915, at which time there was no water in the pool and little of interest found save that the cattails were covered with large black plant lice and their orange-colored eggs. A few large spiders were hiding beneath the leaf sheaths of the cattail. No water bugs were found, though the debris was not sifted. In the Smith pond near-by, adult Notonectids, Corixids and Belostomids were taken in numbers.

The melting of the snows during the winter supplied the basin of the Cattail pool with water again, and the first warm

days of March found Notonectids and Corixids flying to it from the Smith pond. By the last of the month Corixids were laying eggs. April 11 there were not many adult bugs where they had been exceedingly abundant before. The back-swimmer eggs were showing red eye spots. By May 4 the pool was full of activity. Ostracods were exceedingly abundant and Notonectids in first and second instars were preying upon them in numbers. Gerrids in second instar were upon the water and many marshtreaders were upon the floating dead leaves of cattail, mats of algæ and sprouting masses of cattail seed. Corixids from the first to the fifth instar were abundant, but perhaps the larger number were in the third and fourth instars. A few adults were present. The tenth of May was a fine warm day and the Cattail pool was a great place to study young water-bug life. Droves of Gerrid nymphs and marshtreaders made the surface seem a busy place indeed, while the Corixid and Notonectid nymphs were in droves within the water. It was May 17 before the first adults of the spring crop of water bugs were noted in this pool. These were new fledged Corixids. It was May 25 before the Gerrids and Notonectids attained the fifth instar in numbers, and at this time a new bug was dominant upon the floating vegetation of the pool. This was the new adult generation of *Mesovelia mulsanti*, and the presence of large numbers of these silvery-winged forms brought them at once to the attention as they moved about over the green algæ. The green nymphs had attracted little attention in the same situation a few days before. On May 28 most of the Corixids were adult and the pool was roily from a recent rain. The young Marshtreaders were out in force upon this date, and were rivals of the Mesovelias for prey. May 30 the Gerrids were transforming, and the next day the first back-swimmers were seen to emerge into the adult state, yet there were nymphs from first instar up. On the morning of June 3, the notes show that the cattails were in bloom and young plants were encroaching upon the clear water space very steadily. From this day's record and a comparison of the notes of other days regarding the appearance of the stages of the water insects, one is impressed by the remarkable synchronism of development, not only of the water bugs, but hand in hand with them, of the water beetles. And here we find the flowering of the cattail heralding the advent of

a new generation of water bugs. True, many of the bugs anticipate this, especially the Corixids, and many of the backswimmers are tardy, but as a whole, when the cattails bloom, adults of the spring generation of water bugs are at hand.

For days the water had been surveyed for eggs, but none found until on June 17. Corixid eggs were present in numbers. Now, indeed, the days of the pool are numbered, the cattails are steadily encroaching from the west end, and the spike rush bunches are advancing. This restricts the range of true aquatics, but leaves the marshtreader and Mesovelia dominant above. A rain enlarged the pool a few days later, but did not change the circumstances of the life above or within, and after a few days the recession of the pool was resumed. July 8 the water extended only to the edge of the great cattails. Eggs of Corixids and Notonectids were now to be seen again, and the surface was surveyed by both the striders and treaders in numbers.

Surely there must be some truce among these keen competitors of the surface! For here they are all eager for food and not one with scruples against pouncing upon a weaker brother, yet getting on together—a heterogeneous collection from the large Gerrid to the tiny Microvelia. How they manage to maintain an armed truce and survive by their alertness only patient observation can discern.

How often have we been able to study the undisturbed population in the early morning hours when food getting seemed their chief concern! There were the nervous jerky-gaited Gerris nymphs, the agile Mesovelias and the deliberate, stalking Hydrometra. The Gerrids are truly powerful enough and quick enough to clear the waters of their competitors! Why do they not do it? Because, if we may judge from their behavior, there is some mutual aversion that is overcome only by an occasional ravenous appetite. On several occasions, when some bug was intent upon an activity that distracted its usual vigilance, it was caught by a larger bug only to be released again without apparent injury. The capture of a pair of mating Hydrometra by *Gerris marginatus* and their subsequent release is a fair illustration. Mesovelia females attacked while ovipositing were invariably released unharmed. Many instances of the stealthy approach of some predator with ill intent to its prey have been watched with fear for the

safety of the unwitting victim only to see the incident close without an actual attack or with but a brief retention of the captured.

But the above note is beside the issue, and should, perhaps, have been omitted along with the many interesting incidents recorded in the field notes that can find no place in the printed record.

It was noted on July 8 that the pool was restricted by the great cattails on its western margin. By July 14 it was reduced to a few little puddles in depressions made by boot tracks on former visits. Hundreds of little Microvelias, Mesovelias and a number of Hydrometra had followed the waters to these retreats. Saldids were present upon the moist ground round about, while within the water a few Corixids and Notonectids still managed to survive in the ever diminishing quarters. The following day one puddle of water yet remained, a little patch of surface 6 by 10 inches, and upon it crowded together thirteen adult *G. marginatus,* a myriad of winged Mesovelia and a host of Microvelia in all stages. They were making their last stand upon the element that bound them together in common interest. The end of it all was very near. Whither would they go when the last drops sank into the ground, or were taken up by the sun's hot rays? The writer wanted to know. The back-swimmers and boatmen were gone, and even the nymphs disappeared without leaving a carcass. What became of them? There is no clue. Perhaps the adults flew to other quarters while the nymphs in their close confines fell the prey to surface forms. There was only one other possibility, and that a small one. Had the nymphs buried themselves in the mud? To find the answer to this, on July 21, when all the water was gone, the place was visited with a horse and wagon and the mud from the bed of the pool placed in tubs and taken to the laboratory. No living thing was likely to escape, for the mud was only 6 inches deep upon a base of lime stone. Live ostracods were numerous beneath the wet cattail leaves that were prone upon the mud, but no true aquatics in evidence, nor yet their eggs. About the young cattail clumps a few Hydrometra lingered, but the abundant life of a few days previous was gone, leaving no trace of its going nor making any provision for a repopulation by its progeny should timely rains revive the place. No eggs hatched from the rushes or cattail brought in

and no water bugs came forth in the pool transplanted in the laboratory. Thus the "Cattail Pool" comes in the category of the temporary pools that provide range for a spring generation of bugs, but afford no permanent abiding place for this nurtured population.

A Permanent Pool.

The writer is unable to say what has been the past history of Bool's Backwater at Ithaca, New York, but from the topography of its location and the prevailing climate he believes it to be more or less permanent in its nature.

The chief interest in this pool was the presence of the overwintering fourth instar nymphs of *Palmocorixa buenoi* in large numbers. There were some other corixids but not in confusing numbers, and the place was chosen to follow the development of the *P. buenoi* in nature.

Near the upper end of this Backwater there was a little shallow pool connected by a narrow neck of water to the main body during normal times. A constant stream of fresh water came into the main body near by, but made connection with this little pool only in times of high water. The nymphs of Palmocorixa were here by hundreds. Twenty-three were counted as they foraged in a space two square inches in extent. Under the life history of Palmocorixa will be found the advancement of the development of these bugs.

April 19 the *Arctocorixa alternata* were mating while the *P. buenoi* were still in the stage in which they overwintered.

May 9 a wind from the northwest backed the water up so that the little pool was broadly connected with both the Backwater and the Bool's brook. Yet when it was examined the boatmen were seen upon their former foraging grounds though the shore line was several feet beyond the normal. May 11 the water was backed to its former level again. Toward the last of the month the little pool was obliterated by high water for several hours at a time but without changing the population to any great extent. Polliwogs and minnows invaded the pool in early June, and there was some concern as to the effect the latter would have upon the corixid nymphs which were now attaining the adult state. June 8 the water was two feet higher than usual, and for the next week the shore line was six feet out from the normal. The grass along the east bank of the Backwater was submerged and came to be slime coated with

the result that the Corixids came to occupy the added forage grounds in this shallower water, for Corixids are lovers of shoal waters and adapt themselves in time to the oscillations of the pond in which they live. The species of boatmen studied possessed no functional wings and must as a rule be bound to permanent water. But permanent water does not imply that the life within is not subject to varying fortunes and conditions as shown in the notes on Bool's Backwater. For this pool would be threatened with unsightly patches of filamentous algæ during extended dry hot weather, but be cleansed again with the next rains. And these factors enter into the life of the organisms within its waters.

INTERRELATIONS WITHIN THE POOL.

When one undertakes to study the adjustments of any one set of organisms to each other he finds the field restricted and unknown on every hand. He may pursue disturbing factors into other groups only to find these factors held in balance by still other causes, and so *ad infinitum.* Not an organism of the pool can escape the influence of its fellows, and no final analysis can be reached till all are understood.

The pool is indeed a restricted environment and yet only the more obvious facts are known concerning the life within it.

In introducing, therefore, a few ecological notes relating to the water bugs the writer has not the temerity to claim more than a designation of the more apparent features. These are considered briefly in the following outline:

a. Haunts and Habits.
b. Habitat Key.
c. Relation to other organisms.
 1. Parasitism.
 2. Oviposition.
 3. Feeding habits.

While the relation of the water bugs to other organisms is largely a question of feeding habits, it is well to consider first of all the relative location of each form. Haunts and habits determine in large measure the range of influence of each unit in the environment.

In another chapter the families of water bugs are enumerated. There are thirteen of them. Four are limited in large measure to the moist shores adjacent to the water. Two live upon the rafts of algæ and other vegetation floating out from

shore. Two row over the open waters, and five lead a subaquatic life. The first eight are called semiaquatic, the last five true aquatics. The general distribution of these forms is shown in the synoptic table. There are some exceptions, and some structural details have been added to identify genera, so that the table cannot be called purely ecological.

HABITAT KEY TO THE AQUATIC AND SEMIAQUATIC HETEROPTERA.

A. Upon the shore; not running out upon the water, although they may alight there.
- B. Escape by quick jumps and short flights. Antennæ longer than the head. *Saldidæ.*
- BB. Escape by hopping, flying or concealment. Antennæ shorter than the head.
  - C. Beak very short. *Gelastocoridæ.*
  - CC. Beak longer. *Ochteridæ.*

AA. At the water's edge, running out upon the water when disturbed. (Often found upon rafts of floating vegetation.)
- B. Very small plump-bodied bugs, usually black and silver, or mottled with brown.
  - C. Antennæ 4-segmented.
    - D. Tarsal claws anteapical. *Veliidæ.* (genus *Microvelia.*)
    - DD. Tarsal claws apical. *Hebridæ.* (genus *Merragata.*)
  - CC. Antennæ 5-segmented. *Hebridæ.* (genus *Hebrus.*)
- BB. Fairly slender green or yellowish-green bugs. *Mesoveliidæ.*
- BBB. Very slender, elongate bugs. *Hydrometridæ.*

AAA. Coursing upon the water by quick, jerky movements.
- B. Fresh water.
  - C. On quiet or moderately flowing waters.
    - D. Medium to large insects.
      - E. With distinct abdomen. *Gerridæ.* (genus *Gerris.*)
      - EE. Without distinct abdomen.
        - F. Color uniformly dark. *Gerridæ.* (genus *Metrobates.*)
        - FF. Color dark, pictured with yellow. *Gerridæ.* (genus *Trepobates.*)

AAA. Coursing upon the water by quick, jerky movements—*Concluded.*

DD. Small, dark insects, with long, slender legs. *Gerridæ.* (genus *Rheumatabates.*)

CC. On moderately rapid streams or little bays and eddies connected therewith. *Veliidæ.* (genus *Velia.*)

CCC. On the riffles and rapids. *Veliidæ.* (genus *Rhagovelia.*)

BB. Marine. Sometimes far from land Gerridae ~~*Veliidæ*~~ (genus *Halobates.*)

AAAA. Living within the water.

B. Clinging to supports and remaining in contact with surface film.

C. With long respiratory tube at caudal end. *Nepidæ.*

D. In tangled trash (elongate). (genus *Ranatra.*)

DD. In the mud and trash; broad, flat. (genus *Nepa.*)

CC. With short, retractile respiratory tube at caudal end *Belostomatidæ.*

D. Length 1 inch or less, often carrying egg clusters in summer. (genus *Belostoma.*)

DD. Length, 1¾ inch or more.

E. Very large bugs, with fore femora grooved. (genus *Lethocerus.*)

EE. Very large bugs, with fore femora not grooved. (genus *Benacus.*)

BB. Free swimming.

C. Swimming upon their backs, often resting with tip of abdomen at surface. *Notonectidæ.*

D. Very tiny, plump, little creatures, found clinging to aquatic plants. (genus *Plea.*)

DD. Larger forms.

E. Slender bugs, with eyes parallel, dwelling for most part in open waters, where they swim submerged. (genus *Buenoa.*)

EE. More robust bugs, resting with tip of abdomen at surface or clinging to submerged vegetation. (genus *Notonecta.*)

AAAA. Living within the water—*Concluded.*

CC. Swimming in normal position.

D. Clinging to vegetation or swimming through the water with a steady motion. *Naucoridæ.*

DD. Resting on the bottom, rapid, darting swimmers. *Corixidæ.*

PARASITISM.

Very little has been recorded regarding the parasites of the water bugs. All of them, in all of their active stages, are subject to the attacks of the Hydrachnids. These little water mites attach themselves to the bug and remain until adult, when they molt their last nymphal skin and become free swimming. These parasites are often very abundant upon a host, so abundant that they inhibit growth and interfere with the progression of the insect. They are particularly numerous on Ranatra and sometimes disarrange the normal functioning of the caudal air-filaments, as shown in figure 10 on plate XVIII. Corixid nymphs have been noted to show a stunted growth and difficulties in molting, due to the presence of these parasites. Under the discussion of the biology of the Corixidæ is given an account of the seasonal abundance of Hydrachnids.

According to Kirkaldy, who was a careful student of aquatic Hemiptera, the water mites lay their eggs in spring in incisions in soft stemmed aquatic plants or on the underside of leaves. The young larvæ are pale red, and possess six legs, each of which is six segmented. They fasten themselves to water insects by means of sharp hooks at the end of their palpi. Once fixed the head and mouth parts stretch until they become separated by a neck from the main body, the transparent skin of which rapidly swells and elongates to form a bag, with the more solid dark red parts visible anteriorly. The elongated maxillæ penetrate and extend beneath the chitinous covering of the host until they form a long, pointed thread. The legs curl up and become useless and are more or less withdrawn. The larva gradually passes into the pupa stage within this bag, which becomes more and more swollen and rounded posteriorly, and finally bursts to release the adult eight-legged mite. This swims actively about for a time, but before attaining maturity fixes to some plant and undergoes another molt without material change of form. Soars, 1901, discusses

the "Larval water mites of aquatic animals" in the *American Monthly Microscopical Journal,* Vol. XXII, pp. 323-324, and a key for determining Hydrachnids is to be found in "Fresh Water Biology," by Ward & Whipple.

Besides the mites an undetermined internal parasite has been discovered in the body cavities of Notonectids and Corixids. These the writer has frequently seen, as well as spherical spore cysts of a gregarine to be found in the body cavity of Corixids.

Parasitism by Hymenoptera has been observed in a very few cases. These have been egg parasites and belong to the following families: Chalcididæ, Proctrotrypidæ and Mymaridæ. In the first family we have the frequently mentioned *Prestwichia aquatica* Lubbock, which has been reared from the eggs of Notonecta and Ranatra as well as those of beetles.

In the Proctrotrypidæ there are recorded two species at least. *Limnodytes gerriphagus* March and *L. setosus* De Stefani Perez, both of which parasitize Gerris eggs. Matheson and Crosby reared the former species from the eggs of *Gerris remigis* in June, at Ithaca, New York, and also a Mymarid, *Caraphractus cinctus* Walker from eggs which they found inserted in the tissues of plants on December 7. On December 19 some young back-swimmers were swimming about and also some of the little wasps had emerged and were actively swimming in the water. As many as four parasites emerged through one opening in one egg. This parasite uses its wings in propelling itself through the water.

The fact that these notes were made upon eggs inserted in plant tissues and taken in the winter time, limits the host species to *N. irrorata* or one of the Buenoæ, and throws new light upon the wintering of back-swimmers. The species above mentioned are known to winter as adults, though the presence of eggs is not impossible, for one of the European Notonectids is known to pass the winter months in the egg stage. The field of study along these lines would well repay investigation. Brocher has also recorded a hymenopterous parasite from the eggs of Hydrometra. Doubtless there are many other parasites to be found by careful rearing.

No internal parasites of either nymphs or adults of any of the water bugs have been reported in the literature so far as the writer knows.

OVIPOSITION.

The oviposition of the aquatics and semiaquatics does in large measure consist in affixing the eggs to some inert support in the water. Yet there are two conditions wherein other organisms are involved. One, in those cases where the eggs are placed in incisions in plant tissues, and the other where the eggs are deposited upon some animal form.

In the former case the plants are directly concerned. So long as the eggs are merely glued to living plants for support, a safeguard against their loss in the bottom of the pool, they are not considered disturbed by the relation, but when their tissues are punctured and lacerated in the process, there enters a mutual ecological relation.

The Hebrids and Saldids cache their eggs beneath the leaf sheaths of bog-moss and sphagnum, while the latter employ the shore grasses as well. Mesovelia and Rheumatobates are equipped to puncture plant tissues, and the fact that Mesovelia imbeds her eggs in the stems of spike-rush and leaves of cat-tail, has been elsewhere recorded. Members of each of the genera of the Notonectids can be found that make incisions in the stems of money wort and other submerged plants for the reception of their eggs. Two species of the genus Notonecta in this country, *N. irrorata* and *N. lutea,** *Buenoa margaritacea* and *Plea striola* come in this class.

The matter of the Corixid that in large measure attaches its eggs to those portions of the body of the crayfish which are bathed by water currents, is discussed under the biology of *Ramphocorixa acuminata.* (See page 218.) The eggs of this boatman have been found upon smart weed stems of uprooted floating plants and upon dragon fly nymphs, but in very small numbers compared to those affixed to the crayfish. Other Corixid eggs have been found covering the shells of living snails, etc., but in such cases little ecological significance can be attached to the phenomenon.

FEEDING HABITS: THEIR RELATION TO OTHER ORGANISMS.

The aquatic and semiaquatic Hemiptera are, as a group, notorious predators, and the records from an early date are replete with accounts of their voraciousness. The observations

* Judging from equipment of female.

noted, however, deal in large measure with their prowess in mastering insects and other animals larger than themselves. Thus the textbooks on Entomology state the the aquatic Hemiptera are without exception, predatory. We are led to believe that those which dwell upon the surface lead a precarious existence, subsisting upon such uncertain fare as the accidents of nature may provide. In other words, that their food supply consists in the capture of such flies and other terrestrial insects as may chance to fall into the water. One writer in fact has stated that Gerris shows no response to forms meeting the surface film from below. This, however is not in keeping with the frequent observation that Gerris will strike for a back-swimmer nymph that comes to the surface close by.

The writer has pointed out that the food of our common water-strider *Gerris marginatus* consists at certain times of the year almost exclusively of the Cicadellids (Jassids) and related forms that feed on Juncus and spike rush, bordering on and growing in the shallow waters. In checking over the field notes on the feeding habits of these insects, it is seen that much of their food is produced close at hand, both within and about the pool. So, also, with the "toad-bug" *Gelastocoris oculatus*, which has been taken feeding upon lace bugs (*Tingididæ*) reared close by.

Our common species of Rheumatobates, while it does not disdain to feed upon small insects that fall into the water, obtains its main supply from the little crustacean forms such as Ostracods and Daphnians which swarm the quiet pools. These it captures as they rest at the surface, scooping them out and holding them aloft upon the upturned tip of the beak, while the body of the little victim is being depleted of its nutritive material.

The little *Microvelia borealis*, common in Kansas, has access to the same source for its food supply and similar habits of consuming it. *Mesovelia mulsanti* has been observed exploring the sides of stems of rush and cattail that floated upon the surface for Ostracods, which it occasionally obtained, while *Hydrometra martini* stalks about over the floating vegetation in search of whatever small beings chance to come to the surface film. Its victims have been observed to consist of mosquito wrigglers, mosquito pupæ, emerging midges, nymphal Corixids, and Ostracods, as well as small terrestrial insects floundering on the water.

As far as the true aquatics are concerned, according to the texts, which must of course rely largely upon the published records, one and all feed upon insects and other animals in the water. The tendency of the reader, however, is to gather the impression that the prey is large. This is not always true. The large Belostomatids, no doubt, consume considerable numbers of snails, while the bulk of the food of the first three or four stages of Notonectæ consists of small Crustacea: Ostracods, Cyclops and Daphnians with the addition of such other forms as they are able to master. In one genus of back-swimmers, the *Buenoa*, the adults as well as the nymphs, feed very largely upon small entomostracan forms. This is also true of the little *Plea*. Corixids on the other hand find the source of their food supply in the brown sedimentary material on the bottom of the pool. This they scoop up with the flat rakes of their forelegs. These rakes are somewhat spoon-shaped terminal segments or palæ, which are most admirably equipped for their work. The details of the feeding habits of the boatmen are given elsewhere. It is only necessary to call attention here to the fact that they are not predatory in the ordinary sense, that they will strip the chlorophyl from a filament of the spirogyra quite as readily as to gather in the flocculent ooze of the bottom of the pool with its attending population of diatoms, desmids, Euglenæ, Scenedesmus, organic debris, and the Protozoa, rotifers and oligochætes it may contain.

Thus the role played by the aquatic Hemiptera in the society of water forms indicates an intimate relation, not only to the larger beings, but to the smaller Entomostraca and even to the unicellular life of our ponds and pools as well.

It is further to be noted that, while some, like the water striders and back-swimmers, many take advantage of helpless terrestrials upon the water when opportunity affords, the water and its surrounding vegetation supply their chief demand.

ECONOMIC IMPORTANCE.

In these utilitarian days one is asked first of all in regard to the value of his results. If all could but have the vision as Professor Dawson has expressed it in a recent number of *Science!**

* "University Ideals and their Limitations," by Professor Percy M. Dawson, in *Science*, N. S., vol. XLVII, p. 547.

"The scientific attitude is not only agnostic, but also universal. To the scientific mind there are no isolated facts or discrete phenomena, but all are integral parts of the great structure of knowledge. To him the separate sciences and subsciences become of importance and significance only as he sees them as elements of more comprehensive units, which in turn make up the ultimate unit which he calls Nature, Weltanschauung or world picture."

A further justification would be unnecessary. Bueno, in a little paper on the "Ways of Progression in Waterbugs," *Entomological News*, 1906, concludes with the following lament:

"The meagreness of information regarding these habits has led me to the studies outlined above. It is to be hoped that the rising generation of entomologists may give a little less time to hair-splitting classifications and devote its energies to investigations of habits and life histories of other than economically important groups, or than those which, like butterflies, are largely æsthetic; and to such lovers of the insect folk do I look for further light on these highly interesting but financially unremunerative subjects."

The ecological significance of forms has come tardily to the agricultural and horticultural entomologist, but it has come indeed to make a profound impression, as the deeper relations have been understood. It will come more speedily as the farming of the waters takes a larger place in our activities. The problems here are different and the factors so diverse and unknown, that any light upon the interrelationship of aquatic societies will stand as a substantial contribution to the ultimate solution of the baffling problems of the present.

The observations of Swammerdam concerning the predatory tendencies of the water bugs has been followed by numerous records. Merrian graphically figures a large Belostomid in the act of eating a polliwog. Thomas (1871) cites a Corixid as eating fish eggs. Earlier writers mention Corixid eggs, and their use as food by the Mexicans. A few writers indeed have written upon the economic importance of water bugs. Thus Kirkaldy, in an article on "An Economic Use for Waterbugs" (1898), devotes himself to an account of their use as food, and the following notes are from this paper.

Thomas Gage (1625), who traveled in Mexico, mentioned the sale of cakes made of a "kind of froth" from the Mexican lakes. Thomas Say (1832) said that the adult Corixids were used as food in the City of Mexico. Guerin Meneville (1857) publlished a long account on this subject in some five journals, and Virlet d'Aoust (1858) gives a review of the same subject.

The gist of the matter appears to be that at the proper season bundles of rushes are placed in the shallow lakes and upon these the eggs named by the Mexicans "Axayactl" or water-face, are deposited, gathered by the natives and made with meal into cakes. These are eaten *au natural* or with green chilis! They are also cooked without further preparation, having then the appearance of fish roe, when they are called "Auhauhtli" or water wheat. They are said to have a delicate flavor and not to be disdained at fashionable tables. Kirkaldy stated that the dried ova and bugs were being imported into England by the ton for food for fishes.

Aside from these "direct benefits" from water bugs, the numerous notes, such as "A Ferocious Water Bug" and others that have appeared from time to time, record isolated bits of behavior of value in the final summing up of their status.

In a study of the biology of this one group of aquatic organisms some facts of economic value have been brought to view. We have before us now more knowledge concerning the place of the water bugs in the complex of this new field of agriculture than before. Pisciculture, an important branch of this field, is affected, we find, not only by the killing of the young fish by the larger predatory bugs, but by the fact that the majority of them are contenders for the same entomostracans that make up the bulk of the food supply of young fishes.

One group of bugs, indeed, themselves afford some possibility of providing forage organisms for the fish culturist. This is the water boatman, which has been found in the stomach contents of a number of fishes and which forages on the organic ooze, Spirogyra, and other lower organisms of the pool.

Form and Function.

Of all the ecological groups of animals none shows more splendid and ofttimes obvious adaptations of form to function than do those that live in the water. Surrounded by a remarkably uniform element, it is interesting to note how animals of the most diverse classification have been molded to a common plan in response to the physical properties of the medium in which they dwell.

Not only have widely different organisms responded in a similar manner to a common environment, but the very constant and uniform conditions of our fresh waters throughout the world have resulted in the greatest similarity of forms, widely dispersed over the earth.

The insect life of the water affords an especially interesting study since it represents a secondary adaptation. It is believed that insects were all terrestrial in the beginning, but that some have invaded the waters and acquired those structural peculiarities that enable them to cope successfully with conditions in a medium some 775 times as heavy as air.

An examination of the insect fauna of the water will indicate that it is a heterogeneous group, gathered together from the various orders of insects, and illustrating different stages of adaptation.

As Bastin has stated "insects are essentially creatures of the earth and air," but many species have adopted an aquatic life, some to spend only their immature stages in the water, others to linger there throughout most of their days, quitting it only to extend the foraging grounds through flight.

To this latter group belong the water bugs. It is the purpose of this chapter to indicate some of the structural contrivances possessed by these insects, and the manner in which they are used. The chief modifications have taken place along the lines of locomotion, prehension, and respiration, and under these three heads the question will be discussed.

In considering these various questions it is natural to treat the subject from the standpoint of degree of adaptation. This

will be done, beginning with those being the least adapted, and ending with those with most perfect adaptation to an aquatic life.

LOCOMOTION.

In the matter of locomotion of those forms that live upon the waters and shores adjacent, we find all gradations from those that venture but timidly upon the water to those that boldly set forth upon the deep. In fact, there are some that frequent the banks and are found upon the waters only by accident. Such are the Saldidæ, Ochteridæ and Gelastocoridæ. The first family is so called because of the jumping propensities of its members.

As a matter of fact, the members of all three families jump. The first are extremely agile, running and jumping with alacrity, using the wings in tremendously quick flights of a few inches. The last named run or go bumping along like toads. Unlike the well-known Saltatores among the Orthoptera, the hind femora are not notably enlarged. The hind coxæ, however, in some at least, are considerably thickened. The spines of the hind tibia, instead of being arranged on the caudal side, as in grasshoppers and Jassids, are arranged on the opposite and inner side. The middle tibia possesses a few spines, the hind tibia and tarsus many. When the live insect is studied in respect to its locomotion, the position of the limbs makes their armament very clear. These insects rest with femora of hind limbs at right angles to the body, and the front side of the long tibia often in contact with the ground. The tarsal claws are terminal and the fore and middle tibiæ of the Saldidæ bear on their inner distal end tibial combs.

An examination of the members of these three families indicates a superficial resemblance, with the Ochterid bridging the gap between the Gelastocoridæ and the Saldidæ.

The Hebridæ observed by the writer, though occupying the same territory as the Saldids, are equipped more like the Microvelias. The body is covered with a short pile. The limbs, fore and middle, possess tibial combs. The claws are, however, terminal, and in this respect distinguish them from the Microvelias.

The above shore bugs are followed by a mixed lot that extend their range to the floating vegetation. Here belong the Microvelias, Mesovelias and Hydrometras. All of these have the

limbs covered with a close pile, and the last two have the claws still terminal upon the tarsi. This series leads to the Gerrids and Veliids, which habitually traverse the open water. With these the bodies are set with a covering of short close pile and the limbs are long, distributing the weight over a greater surface. The claws are small and subapical, thus affording less likelihood of the limb piercing the surface film. Bueno has figured the remarkable modification of the foot of the middle leg of *Rhagovelia obesa,* and copies of his drawings will be found on plate XI ~~VIII,~~ figure 6. The last tarsal segment is deeply cleft and furnished with a series of ciliated hairs capable of spreading into a fan-like structure. According to Bueno, this fan-like structure spreading from beneath the cleft in the tarsus projects into the water and aids the insect in rowing. Rhagovelia is found in the swiftest part of the streams, and this unique device is a material aid to its locomotion. This bug has the reputation of diving and swimming under water. This habit, however, does not indicate that in any such a way the true aquatics came to extend their range. More probably did it come about by the occasional submergence of some Gelastocorid-like form frequenting the margins of streams and tidal marshes, and clinging tenaciously to its haunts, though occasionally and even periodically submerged. Masen, in *Entomologist's Monthly Magazine,* vol. XXV, p. 236, cites two species of Saldids that move about from plant to plant under water.

Thus we come to the true aquatics. Mr. Bueno gives some observations on the methods employed by the various forms in a paper entitled "Ways of Progression in Water-bugs."

It will be apparent to any who examine the true aquatic Heteroptera that, among them, the Naucorids represent the latest addition to the water fauna. The hind limbs are spiny and angular, like the Gelastocorids, and possess few, if any, hairs that make for efficiency in swimming. The middle tibiæ possess tibial combs like the littoral forms. Unlike their more specialized relatives, they walk very well upon the land.

The Nepidæ also present little modification of the limbs for traversing the water, due no doubt to their "lying in wait" habits. The Belostomatidæ have their second and third pair of limbs flattened and fringed with hairs. Bueno says that "*Lethocerus americanus* when hard pressed and with a free

field, stretches out its raptorial front legs before it, and gives long strong, propulsive strokes with the other two pairs, moved sychronously. When not pressed they paddle slowly, alternating the middle and hind legs."

Of the Notonectidæ the little Plea, living midst the tangles of pond vegetation, makes but short excursions from stem to stem by "short little clipping strokes" of its limbs. These limbs on superficial examination appear but slightly fringed with hair, but careful study will reveal them about as delineated in figure 2, plate XXII. All their limbs end in strong claws. The other genera, Notonecta and Buenoa, have hind limbs obviously set apart for rowing. They are flattened and bordered with close rows of long hairs. These collapse on the return, spreading with the pressure of the pulling stroke. The tarsal claws of the hind limb are so small that they are scarcely discernible amidst the fringe of swimming hairs. These rear limbs, the height of efficiency for propulsion in the water, are suffered to be dragged upon the land, the other limbs already ungainly in their modification for prehension, affording it an awkward means of getting about.

The greatest diversity of limb structure is undoubtedly possessed by the Corixids. The middle limbs are long, lean structures, ending in long, slightly incurved claws. These are employed only in grappling the irregularities of the bottom of the pool, thus holding their owner to their accustomed foraging grounds. The hind limbs fashioned like those of the back-swimmers, are even quicker in their execution. Indeed no water insect has greater agility and darting propensities than has the water boatmen.

PREHENSION.

Kirkaldy once stated that "all of the water forms (with the possible exception of Corixidæ) are raptorial." He later modified this to except the Hydrometra, the front legs of which are not thickened, stating that "although doubtless they are employed for holding the food during feeding, they cannot be said to be noticeably modified for raptorial purposes." In fact, the writer has found that Hydrometra habitually spears its prey from beneath the surface film, and retains it by means of the tremendously long, flexible mandibular stylets which are strongly and retrorsely barbed at their tip. (See plate XXIX, fig. 3.)

Rheumatobates, too, dips below for ostrocods, etc., which it scoops out of the water and holds aloft upon the upturned tip of the beak while the body of the little victim is being depleted of its nutritive material. Microvelia and Mesovelia depend upon their stylets also for holding prey, and the fore limbs are very slightly thickened. The Gerris, Velia and Trepobates have thickened femora and use the fore legs in holding prey. The Saldidæ and Ochteridæ have the front legs modified slightly. In some of the Saldids the fore tibia is armed with a few spines so directed as to be of slight service in grasping. The Gelastocorids have the fore limbs well modified into grasping organs. The femora are thickened and margined with stout spurs. The tarsal claws are heavy and fit against the coxæ firmly. (See pl. IX, fig. 1.)

The Naucorid carries this plan still farther, the femora being greatly enlarged with the tibia and tarsus fitting snugly against it when flexed. In the Belostomatids the same arrangement is found, though not to the same extent. In the genus Lethocerus the femora are grooved for the reception of the tibiæ.

The Notonectids furnish an illustration of still further use of the limbs in the manipulation of prey. These insects do not cling to supports, but poise back downward in the water, thus freeing not only the front pair, but the middle legs as well, for service in retaining captured victims. In the genus Notonecta the femora of both fore and middle legs are large and armed with short spurs and spines. The members of this group are fierce predators and attack other insects often larger than they. (See pl. XX, fig. 8.) On the other hand, it is interesting to examine the limbs of the Buenoa modified for retaining prey—but very different kind of prey. These insects dart, poise and swim submerged, gathering in the Entomostraca by the half dozen, and retaining them imprisoned in a curious crib formed by the long, spiny armature of the flexed limbs. (See pl. XXIV, fig. 4.) Here the femora are not greatly thickened, but long and fashioned with a series of projections that make for efficiency in preventing the escape of small organisms. Notonectæ nymphs feed on ostracods, etc., but seldom retain more than two at one time, and are not in the same class with Buenoa when it comes to

getting the larger plankton of the pond upon which these latter largely feed.

The predatory equipment of all of the above is perfectly obvious when you study it, but there is one large family of water bugs whose external equipment is strikingly peculiar and whose front legs, if used for catching and holding prey, have developed along a line quite remote from the usual form. This family is the Corixidæ. The tarsus of the front leg is flattened, spoon-shaped, and fringed with long hairs. The inner surface of this pala is set with short processes, as seen in the figure (Pl. XXIX, fig. 4). Equipped in this fashion they make admirable scoops for gathering in the flocculent ooze upon which these insects feed. The feeding habits of these insects are elsewhere described in this thesis, and also in a paper that appeared in the Journal of the New York Entomological Society.

RESPIRATION.

The respiration of those that tread or row upon the surface is like any terrestrial Heteroptera, and so our consideration can pass directly to the submerged fauna. On this subject there has been much speculation and some morphological study. The writer has not, as yet, had the time to review the question exhaustively first hand. To arrive at the actual truth it will be necessary to study the structural equipment of each type, and with this foundation, experiment with living material. Of all who have written on the subject, only three have in fact attacked the problem correctly. These are Brocher, Hoppe and Ege. Brocher's work covers a wide field. Hoppe devoted an entire thesis to "Atmung von Notonecta glauca." His results do not agree with Brocher's, and thus the writer does not care to become a third party to the discussions until he has satisfied himself completely. The old idea was that insects carried a store of air below with them. Brocher, however, after removing the guard hairs and modifying the air reservoir equipment in various ways, concludes that most of the air enveloping a submerged insect is expired air! After dedicating a whole series of papers to the records of the prosecution of this phase of the biology of aquatic insects one must consider very seriously his conclusions. The most recent paper on the subject is by Bueno, and appeared in the Annals of Entomological Society of America for December, 1916. Unfortunately this writer

appended no bibliography and gave no hint of an acquaintance with the significant results of the recent European workers. His classification of respiratory types, however, is fairly stated if his interpretation of function be ignored.

I. Dorsal reservoir: Corixidæ, Belostomatidæ and Naucoridæ.
II. Abdominal channel: Notonectidæ.
III. Tube type: Nepidæ.

The Corixidæ make contact with the air by the thorax, while the Naucoridæ and Belostomatidæ connect with the tip of the abdomen, as do the Notonectidæ and Nepidæ. The last named family have prolongations of the eighth abdominal segment, which afford a connection between the air and the spiracular openings, enabling these insects to remain at some distance below the surface.

In matters of meeting the problem of air supply the Corixidæ, though less profoundly modified as to structure than the Nepids, are nevertheless the most independent in their behavior of all the water bugs. The problem of aquatic respiration then is a complex one, and involves further study.

There is yet another phase of hydrobiology that should be mentioned in connection with this chapter. It is the mastery of the physical properties of the water relating to the surface film. Brocher has given us a splendid paper on the fundamentals of this question, to which the reader is referred. He shows the clever devices that enable insects to walk upon the water, to rise out of the water, to break the surface film from below in making contact with a vital supply of free air, as well as to enter the water from above.

It is interesting to watch a Notonectid just alighted upon the water maneuver to submerge. Encased in nonwettable material, the body is buoyed up, and to submerge, the tip of the hind limb, which is wettable and attracts the surface film, is dipped into the water before the head and the film drawn thus over the back, covering the bug and placing him below. In the light of Brocher's work, there are many interesting experiments that suggest themselves concerning the manner in which the water bugs have met and solved the problems of their elected environment.

Notes on the Semiaquatic Hemiptera.

Under this section of the paper, and the next one on page 141, each family is treated under two heads: "A. Taxonomy of the Family" and "B. Biology of the Family."

Under the first head is given the family characteristics followed, perhaps, by a brief historical note, then by a key to the genera. A brief characterization of the genus is given and each genus is provided with a key to its species where possible. Specific descriptions are given for most of the insects listed in Van Duzee's Catalog. Sometimes they have been shortened a trifle if the same information is presented in the synoptic key preceding. In one family comparative notes have been used and in two families undergoing revision (one of them by the writer), the description of species is omitted for the most part.

It is hoped that this taxonomic matter may be found valuable to the general student. The special student, as a matter of course, will go to the sources for his information.

Under the second head, the "Biology of the Family," are given some general notes which relate to the family as a whole. This is followed by a treatment of the species of each genus. Under each species the notes are arranged in a general way as follows: Habitat, hibernation, oviposition, incubation, hatching, behavior of newly hatched, number of instars, maturity, fecundity, longevity, food habits, description of stages, and then a brief summary.

The field of investigation in the realm of the biology of the water bugs is full of intensely interesting and promising problems on every hand. The notes which follow give us some idea of what has been discovered and what yet remains unknown.

Family GELASTOCORIDÆ Kirk 1897.

A. Taxonomy of Gelastocoridæ.

Family Characteristics. More or less squat, toad-shaped bugs, to be found upon the moist sand or mud bordering streams or marshes. The eyes are very protuberant and the entire body often has a mottled, rough, warty appearance. The antennæ are four segmented, shorter than the head, and concealed beneath the eyes. Ocelli are present.* The

* Absent in Nerthra.

rostrum is short, stout and four segmented. The fore legs are strongly raptorial. The limbs are more or less spinous. The fore and middle tarsi are one segmented, and the hind tarsi two segmented. (Under a lens Gelastocoris appears to have two segments in middle tarsus, one a very short one, and three in the hind tarsus, the basal one a short one. Cleared and mounted limbs show the long segments to be attached to the tibiæ.)

Three genera are present in this country. *Gelastocoris* Kirk., *Mononyx* Lap. and *Nerthra* Say. The first enbraces three species, each of the latter, one, a total of five species for America north of Mexico.

Historical Review. Most of us have learned to know these bugs under the name *Galgulidæ,* though they have been given by turns the names *Mononychidæ* and *Nerthridæ.*

KEY TO GENERA.

A. Fore wings free.
  B. Fore tarsus with two claws. *Gelastocoris.* (Galgulus)
  BB. Fore tarsus with a single claw. *Mononyx.*
AA. Fore wings fused together on the back. *Nerthra.*

Genus GELASTOCORIS Kirk.

Variously marked, often mottled, exceedingly variable bugs of a broad flat appearance. The eyes are very protuberant and the antennæ concealed beneath them; have the third segment very short and small, and "completely connate with the fourth." All the tarsi end in two strong claws. In ventral view the terminal abdominal segments of the male are seen to be asymmetrical. (See pl. IX.) In the female the 6th ventral segment is more or less convex along the middle. In 1901 Champion said that Montandon's monograph of this genus would appear shortly. In 1905 Bueno wrote that the only way to determine the species was by comparing the notes given by Champion. The writer has not yet found Montandon's monograph. The key to the three species is made from Champion's notes. Bueno has said that he is aware of several undescribed species.

KEY TO GELASTOCORIS

A. Lateral angles of pronotum rounded, moderately dilated and finely crenate. Pronotum slightly constricted. *G. oculatus.*
AA. Lateral angles of pronotum acute.
  B. Lateral angles of the pronotum transverse or subtransverse along their anterior edge, distinctly crenate in front and behind. Spots on elytra well marked, often more or less ocellated. *G. variegatus.*
  BB. Lateral angles of the pronotum oblique in front and less coarsely crenate. General coloration more obscure than in species above. *G. vicinus.*

G. Oculatus Fabr. 1798.

Fabricius, Ent. Syst. Suppl. p. 525.

G. oculatus is the only one recorded as general in distribution. The others are neotropical. This widely distributed species has been taken in Kansas, Oklahoma, Colorado, Arizona, Minnesota, Illinois, Michigan, Ohio, North Carolina, Florida, Georgia, Carolina, District of Columbia, Maryland, Pennsylvania, New Jersey and New York. The original description of this species is very short and inadequate. Uhler says:

Our *Galgulus oculatus* is a variously tinted chunk of insect entity, thick in front, horizontal, and gradually thinning towards the bluntly curved posterior end of the abdomen. The form thus resembles an Indian hoe or stone skindresser. The sides of the prothorax are expanded into thin, bent lobes, before which the margin is deeply sinuated, and then rises into the smaller, hollowed lobes which fit against the eyes. These lobes are ivory white beneath, and next to them the pleural depression is covered by fine, dense, pale granules on a dark spot. The upper surface is mud-brown of any shade, or it is red if the creature lives in a soil charged with oxide of iron, or blackish brown in carbonaceous mud, or clear light brown if developed in clean, sandy loam, or flecked with silvery white on a mottled and variegated more or less olive greenish ground, when its birthplace and home are in the micaceous mixed soil. Almost the entire upper surface is closely set with fine raised granules, which give it a velvety appearance in some lights. Occasionally it frequents places where green slime accumulates between the stones near the bed of a brook, and then it is apt to be covered, and even permanently penetrated by the bright green color of the algæ. The legs are pale yellow, banded with brown; the stout, compressed fore thighs are generally brown, interrupted by short, yellowish, transverse marks, the underside armed with marginal, close set, piceous, short teeth, separated by a longitudinal groove into which the spinous, bent, banded fore tibiæ fit. The latter are also armed with a bunch of long spines a little way from the base, and between the others there are numerous more slender, shorter ones, which are continued upon the tarsi. The apical tarsal joint is also finished by a pair of long curved nails. The other femora and shanks are likewise banded with pale brown, and have a pair of long piceous curved nails."

G. variegatus Guer. 1844.

Guerin. Icon. Ins. p. 352.

This well-named species has a more definite or distinct pattern than the others. Champion says it is the most beautiful of the genus. "The pronotum is subparallel at the sides in front, the lateral angles are foliaceous, very distinctly crenate in front and behind, and transverse or subtransverse along their anterior edge."

Taken in Texas, California, New Mexico.

G. vicinus Champ. 1901.

Champion, Biol. Centr. Am. Heter. II, p. 349.

It would appear that Montandon had named this in his notes and sent some of the bugs to Champion for examination. Champion says: "It is very like *G. variegatus* but has the foliaceous lateral angles of the pronotum, more oblique in front (instead of subtransverse), and less coarsely crenate. The pronotum is strongly constricted at the sides behind the anterior angles, the margins being subparallel in front. The general coloration is usually more obscure than in *G. variegatus*."

Neotropical in distribution.

Genus MONONYX Lap.

In these bugs the body is more quadrangular than in *Gelastocoris*. The thorax being fully as broad as the abdomen. The adults have one strong claw on fore tarsus instead of two as in *Gelastocoris*. The antennæ are 4 segmented, the third segment being narrow, "barely one-third the length of the fourth and almost connate with it." Champion.

Mononyx fuscipes Guer. 1843.

Guerin Rev. Zool. for 1843.

This neotropical insect has been recorded for California. This species of Mononyx has the fore femur widest toward the base. The last segment in the male is small and placed considerably to the left of the longitudinal axis of the body, and the preceding ventral segment is foveate on the right side near the margin. In the female the two triangular pieces forming the last segment are broader than long, and the sixth is not very deeply emarginate.

Genus NERTHRA Say.

Shape suboval, depressed; head short and broad; scutellum small; hemelytra entirely coriaceous and linearly roughened in prominent points, soldered together along a straight suture indicated by a groove. Rostrum small. Anterior femora basally incrassate; tarsal claws single. Abdomen rounded. Male genital segments laterally deflected.

Nerthra stygica Say 1832.

Say Heter N. Harm, p. 37.
Bueno, Ohio Nat. Vol. V, p. 287.

"Moderate in size, suboval, depressed; head short and broad with four tubercles in the middle, the outer two less elevated than the middle two; triangular in front and reflexed. Eyes reniform, not very prominent. Ocelli absent. Rostrum short, small and so hidden under the head as to be hardly visible (joints not counted for this reason). Prothorax, sides subparallel, curvedly converging in the cephalic third; base slightly sinuate; laterally flattened; apex nearly straight except at the eyes; disk much elevated and roughened. Scutellum triangular, sides sinuated, much roughened. Hemelytra slightly flattened and dilated at the humeral angles and gently curvedly, sloping to the rounded extremity; entirely coriaceous and linearly roughened in acute elevations along the lines of the sutures; soldered into one piece along a straight sulcate suture extending from the caudal angle of the scutellum to the tip of the hemelytra; apparently soldered to the scutellum as well; not entirely covering the abdomen, the connexival segments being moderately visible beyond the costal margin; extending beyond the end of the abdomen. First pair of legs raptorial. Anterior femoræ incrassate, flattened anteriorly and coming to a point; coarsely granulate; tarsal claws single. Intermediate and posterior pedes cursorial; femoræ normal with a row of blunt teeth; tibiæ with two rows of stout spines with a sulcus between; tarsi one-jointed in intermediate pedes and provided with double claws (tarsi of posteriors lost in the specimen before me). Mesosternal tubercle rather acute and laterally somewhat flattened, terminated by bristles. Male abdominal segments much compressed in the middle to give room for the large and prominent genital segments which are deflected toward the right. Abdomen rounded, with an entire margin.

"Color, blackish-brown above, except the flattened prothoracic and hemelytral lobes which are yellowish and translucent. Underside of the

abdomen more or less black. First pair of legs entirely black; second and third more or less spotted with lighter color.

"Dimensions: Insect—Long., 7.4 mm; lat., 5.3 mm. Head including eyes—Long., .6 mm; lat., 3.4 mm. Prothorax—Long., 2.4 mm; lat., 5 mm. Abdomen—Long., 4.4 mm; lat., 5.3 mm.

"Redescribed from a single specimen in the collection of Mrs. Annie Trumbull Slosson, who took it in Florida.

"The much roughened upper surface together with the entirely coriaceous hemelytra fused into one will at once distinguish this species from all the other Mononychinæ.

"The preceding descriptions will doubtless be found lacking in many respects, but dissection being necessary to determine certain anatomical features and characters, such, for instance, as the antennæ, the possession of only one specimen, and that not my own, has made it impossible to supply what is missing."—*Bueno.* He adds:

"As Say's description is not accessible to all, I give it hereafter taking it from the Le Conte edition":

"*N. stygica.*—Black, front quadrilineate.

"Inhabits Georgia.

"Body oval, brown-black, rather rough; head crenate on the front so as to form four denticulations; eyes rounded, rather prominent; thorax not emarginate before, with a slightly depressed margin behind; anterior thighs dilated triangular; hemelytra with oblique lines; they appear united at the suture.

"Length three-tenths of an inch.

"I have but one mutilated specimen which was sent to me by Mr. Oemler. If I am not deceived by this specimen, the species is apterous and the hemelytra are united by a rectilinear suture, which will require the formation of a separate genus which may be named Nerthra."

This rare insect has been taken in Florida and Georgia.

B. Biology of the Gelastocoridæ.

General Notes. These strange bugs are to be found about the moist grounds bordering streams or other water bodies. Some of them dig burrows into the sand or mud. They feed upon other insects, pouncing upon them with a sudden jump. Their general shape and coloring render them difficult to discern in their native haunts.

Genus GELASTOCORIS Kirk.

Biology of *G. oculatus.*

Habitat. Uhler has told us how the color varieties harmonize with the bug's surroundings. (See description above.) We have found those on mud flats slate color, and those on the river sands mottled and pebbled like their dwelling place. It is found amongst the "stones and low banks of brooks and streams" or upon the barren sands of the river flats. These bugs are gregarious and peculiarly local in distribution. A colony may be found in one spot along a given stretch of the stream and nowhere else.

Hibernation. Bueno took these bugs in their second instar at Long Island in late September.* He found no adults, from which he inferred that they hibernate as nymphs.†

Mating. The writer is not aware of any observation on this point. The sexual differences due to the asymmetry of the male was noted as

* Three Days in the Pines of Yaphank., Can. Ent., July, 1912.

† Our Kansas forms winter as adults, burying themselves in the sand.

long ago as Brulle's time at least, (1836). Figures of this difference are shown on plate IX.

Oviposition. It has been stated that the eggs are deposited in the ground, but the writer has not been able, so far, to verify this point. The ovipositor parts bear strong, dull tipped spines or pegs, that might well serve the purpose of pushing aside the sand grains. A drawing of these parts is shown on plate IX.

Number of Instars. From the collection of nymphs there are certainly five instars. Uhler says there are two broods in the east. The second one coming in August.

Food Habits. Again we get some observations from Uhler who writes most vividly of bug behavior: "They may often be seen in the month of May walking about between the stones on the low banks of brooks and streams, where *Tettix* and *Batrachidea* abound, watching an opportunity to seize one of these insects, and when the favorable moment arrives, leaping suddenly upon one of them, clasping it with tight embrace between the front femora and tibiæ, and there sucking out all its vital juices." Professor Thomas reported its capture of *Xya terminalis* in the same way. Uhler says it uses little discrimination, seizing the larvæ of ground beetles, and almost any other kind of insect which comes its way.

The writer submits a photograph herewith (plate V) to indicate the greediness of these bugs, and the fact that their food source was close at hand. The lace bugs in this case were reared on the vegetation near by. Some bugs were taken with a half dozen lace bugs held in one embrace. Another one had some small Capsids.

Behavior The writer found these in greatest abundance near Russell Springs, in Logan county, and from the river a few miles north of ~~Greeley~~ Sharon Sp., in Wallace county, Kansas. Mr. Alexander brought in splendid series from Pawnee county, Kansas. These insects jump quickly when disturbed, and squat flat upon the sand where the mottling of their backs merges into their surroundings, rendering them well nigh indiscernible. The position of their hind limbs and the location of the spines of the tibia, where they will best serve their purpose, is an interesting adaptation to use. See photo., plate IV.

DESCRIPTION OF STAGES.

The Egg.

Up to date the writer has not been able to follow the life history of the toad bug. Mr. C. P. Alexander brought in from Larned, Kansas, a considerable series of adults and last instar nymphs. From this material the writer has figured the ovipositor of the female, and the ovum. One female contained 10 ova. The mature egg meets the following description.

Size. Length, 1.25 mm; diameter, 91 mm.

Shape Broadly oval, as shown on plate IX.

The surface is roughly granular, and marked into irregular hexagonal areas by thickened ridges of the chorion.

The Nymph.

In the last nymphal instar the wing pads reach to the base of the abdomen. The lateral margins of the prothorax are flattened but not "buckled" or constricted as in adult. The hind tarsi are single segmented. Ocelli are present! In *Mononyx fuscipes,* Champion says the ocelli are absent in the nymph. This is the usual case.

Genus MONONYX Guer.

So little is recorded in regard to the biology of the species that some one should rear it. It is predatory, as was long ago recorded.

Champion says that the adult has only one claw on its fore tarsi, the nymph of *M. fuscipes* has two long claws. The segments of the intermediate and hind tarsi are fused into one, and the third and fourth antennal joints are connate. The ocelli are absent.

Habitat. "These insects live in muddy places on the banks of ponds and streams and are usually coated with an earthy incrustation, which cannot be easily removed."

Family OCHTERIDÆ Kirk. 1906.

A. Taxonomy of the Ochteridæ.

Family Characteristics. Shore bugs with characters intermediate between those of *Saldidæ* and those of *Gelastocoridæ.* The general appearance is also intermediate, resembling some of the Saldids, perhaps more than the toad bugs. The antennæ are four segmented, shorter than the head, but exposed. The eyes are prominent, two ocelli present. Fore femora slightly if at all fitted for grasping. Rostrum is long, like that of the Saldids, reaching the hind coxæ. The first and second segments are short, third, very long and slender. Tarsi are given by Parshley as two-segmented behind, with a question mark after the statement "front and intermediate tarsi one-segmented." We have but two specimens in the Snow collections at University of Kansas. The middle tarsi appear two segmented under binocular. Professor Barber's drawing of his *Ochterus banski* shows three segments in hind tarsi and two in each of the others.

Historical Review. There is but one genus in the family. *Ochterus* Latr. 1807. He suggested the name *Pelogonus* for this genus two years later because he believed *Ochterus* was preoccupied. It is under the name Pelogonus that Uhler mentions these insects. The genus is sufficiently characterized by the family description. A more nearly complete description can be found in Amyot & Serville, page 407.

KEY TO SPECIES OF OCHTERUS.
(After Barber.)

A. Clavus entirely yellow. *O. flaviclavus* Barber.
AA. Clavus concolorous.
  B. Entire lateral pronotal margins broadly pale. *O. banksi* Barber.
  BB. Lateral pronotal margins, with only a pale spot anteriorly. *O. americanus* Uhl.

O. flaviclavus Barber 1913.

Can. Ent. XIV, p. 215.

"Brownish-black. Very much the appearance of *O. americanus,* to which it is closely related, having the usual carinate and rugulose face. However, somewhat smaller than that species with the clavus entirely yellow. The pronotum with the lateral margins gently rounded, more converging anteriorly, the anterior margin being narrower than the width across the eyes; the anterior angle of the pronotum sharply rounded and not projecting anteriorly as in *americanus;* the expanded part of lateral margins narrower, with a small yellowish spot just posterior to the anterior angle; the humeral angle almost rectangular, projecting but a trifle beyond margin of corium. Extreme edge of corium very narrowly pale, but the usual pale marginal spots are lacking. Surface with the usual pearl grey spots. Beneath, with the sternum slate grey; the acetabula, posterior and lateral flange of the prosternum, elytral flange anteriorly, posterior margin of metasternum, legs and venter, pale; legs lightly infuscated. Prosternum, mesosternum, externally, and metasternum before the posterior angle, distinctly punctate.

"Length, 3½ mm.; width of pronotum, about 2 mm.

"Described from a single male in the collection of Mrs. Annie Trumbull Slosson, taken by her at Ormund, Florida."

O. banksi Barber 1913.

Can. Ent. XIV, p. 214.

"Broad ovate, brownish black. The head, behind the vertex, opaque, from there anteriorly, shining and obliquely, finely rugulose and tricarinate; one carina next each eye and a median one, continuous from vertex to apex; transversely sulcate midway between ocelli and base of head. Pronotum with anterior margin almost truncated, with the anterior angles next the eyes rounded and not projecting forward or outwardly beyond the exterior margin of the eyes; entire lateral margins gently rounding posteriorly; humeral angle rounded, not very prominent; lateral margins broadly expanded, pale; this mark broadest about the middle, more abruptly rounded anteriorly, and tapering posteriorly to occupy the entire margin; the remainder of the surface brownish black, elevated and transversely, but not very deeply, sulcate a very little behind the middle; posterior lobe, middle and anterior part of first lobe more coarsely punctate, the latter with two or three transverse weak furrows. Scutellum almost equilateral, rather coarsely punctate and transversely furrowed; anteriorly with a transverse elevated ridge, behind which it is depressed. Corium not demarked from membrane, broadest across the middle, with lateral margin gently rounded to just beyond middle, where it more abruptly rounds off to the rather narrow apical part of membrane; the external margins either broadly pale throughout or in part suffused with fuscous and reflexed, without the usual series of pale marginal spots which occur in *O. americanus.* Clavus and corium, anteriorly, with coarse scattered punctures. Nervures of the membrane indistinct. General surface with indications of the customary bluish grey markings, unless denuded, when the whole upper surface is smooth and shining. Beneath on sternum and venter paler, with rostrum, acetabulæ, coxæ, legs and external angle of metathorax pale yellow. Prosternum rather coarsely punctate.

"Length, 4 mm. Width of pronotum, 2 mm.

"Described from three males and one female collected by Mr. Nathan Banks of Glencarlyn, Virginia, in June. Judging from the meagre descriptions and indifferent illustrations at hand, I am led to the opinion that this species is most nearly related to *O marginatus* Latr., of Europe. But having no specimens of that species for comparison, I am, at this

time, unable to settle the point. *O. banksi* can readily be separated from *americanus* by its difference in color, markings, and the character of the pronotum. Apex of membrane is more narrow than in *americanus*."

O. americanus Uhl. 1876.

Bul. U. S. Geol. Geog. Surv. 1, p. 335.

"Broadly oval, slaty-blackish, opaque, the pronotum a little narrower than the abdomen. Head polished, minutely punctured in part, invested with very sparse prostrate pubescence, which is more dense beneath; rostrum reaching the end of the second ventral segment, blackish-piceous on the swelled base, the remainder pale rufo-testaceous; antennæ pale piceous; face obsoletely carinate, each side with a series of oblique wrinkles, its anterior and lateral boundaries carinated. Pronotum transverse, velvety blackish, with a few short wavy lines and some dots of bluish lead-color, and remotely golden pubescent; the lateral margins slightly oblique, only a little narrowing anteriorly, and rounding against the anterior angles, which are distinct and almost acute; touching the margin a little way back, each side, is a small triangular yellow spot; posterior angles subrectangular; the posterior margin waved each side of the center, where it is also a little yellowish. Pectoral surface dull black, with very sparse sericeous scales exteriorly; the spots of the dorsal margin equally visible beneath; sternal margins piceous. Legs dull pale piceous-yellow. Hemelytra broad, widening posteriorly, velvety black, pubescent, sprinkled with golden pubescence, spotted and dotted with bluish lead-color; the costal margin yellow, and with five small yellow spots; membrane bluish lead-color, with the nervures black. Venter piceous black, densely, minutely sericeous pubescent, the edges of the segments and the tip of the last one a little reddish-piceous. The connexivum is unspotted, and the surface of the tergum black, polished, with rufo-piceous edges to the segments.

"Length, 5 millimeters. Width of pronotum, 2½ millimeters. Width across the hemelytra, scantily 3 millimeters."

Has been found in Nebraska, Illinois, Texas, Arizona, Massachusetts, New York, New Jersey, Pennsylvania, Maryland, North Carolina and Florida.

B. Biology of the Ochteridæ.

General Notes. These bugs are spritely fellows, dark in color, that live upon the shores. They are predatory in habit.

Habitat. Uhler says of *O. americanus*: "This is a gay, active little insect, which measures only one-fourth of an inch in length, and lives among the grass and weeds on the margins of brooks and ponds from Massachusetts to Texas.

Hibernation. Dufour said that these insects appear in April. Thus they overwinter as adults. Practically nothing is known of their life history. Dufour describes the nymph of a species. But concerning the egg, number and length of the instars, etc., we have no data.

Feeding Habits. Uhler says that the fore legs of *O. americanus* "are slender and fitted for running, not calculated for seizing and holding prey, as in *Galgulus* and *Mononyx*. The rostrum is, however, a dreadful instrument, sharp as the finest needle, extremely thick and stout at the base, and a deadly probe to a poor larva of horse-fly or other insect which lives next to the surface of the ground in situations near water."

Family SALDIDÆ Amyot & Serville 1843.

A. Taxonomy of Saldidæ.

In the treatment of the systematic part of this family the writer has been fortunate enough to secure the loan of the Hayden Geological Report of 1877 from the John Crear Library, of Chicago. This contains Uhler's monograph of the Saldidæ and the descriptions of all but a dozen of those listed in Van Duzee's checklist. These latter have been gleaned from the various sources in which they appeared.

Uhler stated at the time (1877) that only one genus was used but that good characters could be found for erecting others. Thus Reuter in his paper "Zur generischen Teilung der palaarktischen und nearktischen Acanthiaden" separates the family into 13 genera, eight of which are his own. This paper appeared in "Ofversigt af Finska Vetenskaps-Societeten Forhandlingar Bd. LIV, 1911-12, Afd. A. N. 012," which, by good chance, was found in the exchange library of the *Kansas Science Bulletin.* As the title indicates, the paper is in German, but the tables and descriptions are in Latin. The writer has essayed to adapt the tables to the genera recognized in Van Duzee's list and to render in English his generic descriptions in part:

"Family SALDIDÆ (A. & S.) 1843.

"Form oval or long-ovate. Eyes large, strongly exserted, inner margin posteriorly emarginate or sometimes only subsinuate. Ocelli two, distinct or very rarely united into one. Rostrum three-segmented, first segment very short. Antennæ much longer than the head, four-segmented, subfiliform or two terminal segments enlarged. Pronotum trapezoidal, with the anterior side much the shorter, lateral margins oblique, with the edges recurved and the submargin depressed; the latero-posterior angles overlapping the base of the scutellum. Xyphus of the prosternum short, triangular, the prosternum short, projecting backward like a lid, over the base of the anterior coxæ, the propleura with a roundish pit beyond the anterior angle of the prosternum. Mesosternum grooved, with the coxæ placed moderately close together. Metasternum deep-seated, the coxæ in contact at the base. Hemelytra without cuneus. Membrane with looped nervules, forming a transverse series of four or five long areoles. Posterior coxæ cardinated, broad. Posterior trochanters very long, acute, placed on the inner side of base of femora; the posterior femora and tibiæ longer than the others. Anterior femora slightly thicker than the others. Tarsi three-segmented, first very short. Male genital segment with a dorsal apical opening, with two curved styles converging apically. Last ventral segment of female retrorse, usually produced, rounded, plate-like, covering the genital segments, apex rarely truncate and exposing the genital segments."—*Uhler and Reuter.*

"The posterior legs are thrown very far back by reason of the very large and long coxæ, and, together with the long femora and tibiæ, give them a great facility in vaulting into the air. They use their wings in connection with this motion, and generally alight several feet from the point of departure. Their motion in running over the ground is often sinuous, while rapid, and their selective adherence to the spots which best agree with their combination of colors may well shield them from the pursuit of enemies."—*Uhler.*

This family Saldidæ is represented in America by eight genera and thirty-two species. Reuter recognizes two subfamilies which may be separated as follows:

KEY TO SUBFAMILIES.

A. Vertex rather broad. Inner margin of eyes posteriorly emarginate. *Saldinæ.*

AA. Vertex narrow. Inner margin of eyes posteriorly subsinuate. *Saldoidinæ.*

Subfamily SALDINÆ.

Eyes with inner margin posteriorly emarginate. Vertex rather broad. Second segment of antennæ distinctly longer than the third. Anterior part of pronotum marked by a large transverse oval callosity. This callosity often extending beyond the middle. Its disc usually marked by a median foveola. Posterior disc usually marked on both sides by a longitudinal impression reaching to the callosity. Lateral margins entirely carinated.

KEY TO GENERA OF SALDINÆ.

A. Pronotum, sides being more or less flattened, front callus never reaching to the lateral margins of the sides. Sulcus behind this destitute of punctures and longitudinal wrinkles. Most rarely of all marked with punctures, in this case apex of pronotum almost as wide as head with the eyes.
   B. Membrane marked with five entire areoles, last ventral segment of female truncate. *Pentacora.*
   BB. Membrane marked with four or five areoles of which the subexternal is shorter than the rest, third and fifth more or less contiguous toward the apices.
      C. Apex of pronotum almost equal in width to the head, a little wider than this. Hemelytra densely and usually distinctly punctulate or subcoreaceous. Posterior tarsi with second and third segments subequal in length, body often wide, membrane usually with five areoles, of which the subexternal one is shortened. *Chiloxanthus.*
      CC. Apex of pronotum narrower than head, rarely as wide as this, in this case the hemelytra not punctate. Membrane always four-areolated.
         D. The membrane with its first area or inner base prolonged two-fifths or one-half beyond the base of next area. Hemelytra often punctate, always destitute of sericeous patches. Embolium entirely black. *Salda.*
         DD. The membrane having its first area or inner base prolonged slightly or not more than a third of its length beyond the next area.
            E. Corium with two entirely distinct veins, inner one furcate toward apex, branches touching the suture of the membrane. First area of membrane or anterior apex usually touching, or nearly touching apex of second. *Saldula.*

KEY TO GENERA OF SALDINÆ—*Concluded:*

EE. At least the inner vein of the corium destroyed toward apex. First area or interior apex of membrane distinctly placed above the apex of the second, very rarely almost touching this. In this case two veins of corium obsolete. Hemelytra entirely or nearly opaque or sericeo-opaque. *Micracanthia.*

AA. Apex of pronotum always distinctly narrower than the head with the eyes. Apical stricture distinct. Callus strongly convex, terminated by anterior and posterior deep sulci. Marked with punctures and little longitudinal wrinkles.

B. Toward apex of pronotum quite strongly narrowed, sides straight, callus by no means touching lateral margins, leaving a rather broad margin extended a little behind the middle. Hemelytra opaque, only the costal area of corium and embolium being shiny. Ocelli slightly distant. *Ioscytus.*

BB. Toward apex of pronotum strongly narrowed, sides more or less sinuate. Callus occupying all or nearly all of the width of the pronotum, leaving only a narrow or very narrow margin. Ocelli very little separated. *Lampracanthia.*

Genus PENTACORA Reuter 1912.

"Body oblong. Eyes slightly converging anteriorly. Ocelli slightly distant or subcontiguous. Tip of rostrum reaching apex of intermediate coxæ. Second segment of antennæ as long as width of head, or distinctly longer. Pronotum toward the apex moderately narrow, broadly emarginate at base. Sides flattened, lateral margins toward apex strongly rounded or forming distinct angles. Callosity by no means touching lateral margins, transverse impression placed behind the middle of the disk, the scutellum, longer than broad, impressions far remote from base. Hemelytra often densely and usually distinctly punctulate. Interior vein of corium furcate toward tip, branches touching suture of the membrane. Membrane marked by five oblong areas, first or interior area moderately produced beyond the base of second. Apex almost attaining apex of second. Third segment of posterior tarsi a little shorter than second, or subequal to it in length. Last ventral segment of female slightly produced, genital segment by no means totally hidden. Type *Acanthia signoreti* Guer. Three Nearctic species, *signoreti* Guer., *ligata* Say, and *hirta* Say."

Pentacora signoreti (Guerin) 1857.

Salda signoreti Guerin, La Sagra's His. Nat. de Il'Ile de Cuba, Hemipt., 401, pl. 13, fig. 10.
Acanthia signoretii Stal, num. Hemipt., III, 148, No. 1.

"Oval, sand-yellow with black markings, or black with sand-yellow markings, all over minutely sericeous pubescent. Head more or less marked with black between the eyes and behind, omitting the amber ocelli and two spots on the vertex, or with only two small black spots on the vertex; gula with a broad black spot; the emarginated inner side of the eyes generally black. Antennæ yellow or pale piceous, the basal joint black beneath and at base; second joint blackish or dusky beneath; third and fourth sometimes blackish beneath, the latter almost as short as the basal one, the third longer. Rostrum reaching to behind the middle coxæ, piceous or black, with the basal joint pale. Face with a longitudinal groove, and the cranium with a few wrinkles and ridges. Pronotum wide, deeply concave behind, with the humeral angles drawn out obliquely into

broad, flat lobes, with a little hump at the outer corner; surface finely pubescent, closely, finely, obsoletely punctate; with a dull black spot on the disk of the anterior lobe, which sometimes runs back narrower to the base, and on each humeral angle a black spot. Antepectus sand-yellow, but generally with the middle line of the sternum black; mesosternum, excepting its lateral lobes and posterior margin, black; metasternum also black. Legs sand-yellow, the coxæ more or less black, as also the apex of the tibiæ, and a band on the tips of the second and third tarsal joints; nails generally testaceous. Scutellum black, minutely punctate, finely pubescent, arcuately impressed before the middle and with a slight elevated hump each side, usually carrying a yellow spot; the apex acute broadly yellow, or with two yellow, approximate spots, the lateral edges sometimes yellow. Corium sand-yellow, or whitish and yellow, minutely punctate and pubescent, marked with black or fuscous in very varying proportions, generally with a double black spot on the costal area before the middle, a similar spot behind the middle, and a smaller rounded one at tip; disk next the clavus and the clavus fuscous or blackish, the latter sometimes with a small yellow spot near the inner posterior angle, the former very often with a large yellow spot in the middle of the posterior margin, and often the margin itself yellow; membrane sand-yellow, sometimes clouded with fuscous, and with a short transverse black band at base, the nervures piceous, long, and nearly straight. Venter pale yellow, finely pubescent, more or less blackish at base, and streaked on the disks of the segments each side, and sometimes with a row of black points a little way from the lateral margin; the genital segments and ovipositor more or less blackish. The spots on the costal area are frequently wanting, or have only traces present; occasionally the tip of the slender cuneus is black. Generally the whitish spots at the apex of the discoidal area of the corium are present and very conspicuous.

"Length to tip of venter 5-6 millimeters; to tip of membrane 6-7½ millimeters. Width of base of pronotum 2½-3 millimeters.

"First obtained in Cuba; afterward in Sonora, Mexico; since then on the sea coasts of Massachusetts, North Carolina and Georgia. I have met with it in large numbers on the sea coast of Worcester county, in Maryland, in July and August. It lives on the pale sands not remote from the beach, and the darker varieties may be met with running briskly over the gray or blackish sandy mud, neglecting the dry spots, but often swarming upon the moist places.

"The genital segment of the male has a long, curved, acutely tapering appendage, and two shorter and straighter approximate ones in the middle, superiorly."—*Uhler.*

In the matter of distribution, Van Duzee adds New Jersey, Florida, Texas and California.

Parskley adds New Hampshire.

Pentacora hirta (Say) 1832.

Acanthia hirta Say, Heteropt. New Harmony, 34, No. 2.

"Brownish, darker before. Body densely hairy, dull yellowish-brown or fuliginous; head a little darker at base; thorax blackish before the transverse line. Scutel blackish. Hemelytra conspicuously hairy, with dull yellowish spots, as well on the membrane as on the corium. Pectus a little varied, with the remaining inferior surface, including the feet, immaculate.

"Length to tip of hemelytra under one-fourth of an inch.

"This species may be recognized by its more obviously hairy vesture; its color is also paler than usual in this genus. Inhabits Indiana."—*Uhler.*

To Indiana, Van Duzee adds Quebec, Connecticut, New York, New Jersey, Florida and Texas.

Pentacora ligata (Say) 1832.

Acanthia ligata Say, Heteropt. New Harmony, 34, No. 1.

"Form the same as in the *Pentacora signoretii,* black, a little shining. Head a little narrower, black, with a yellow arc on the arched base; the margins of the orbits of the eyes, the cheeks, tylus, and collum of the throat more or less yellowish; vertex with two impressed oblique lines converging before the ocelli, a short, longitudinal one outside of each ocellus, and a short, wide groove on the middle of the raised front; the front generally bounded beneath by a transverse yellow band. Rostrum reaching upon the intermediate coxæ, slender, piceous, the basal joint yellow, with its apex black. Antennæ piceous or black, the basal joint paler above, short and thick; the apical joint a little shorter than the third, but very much longer than the basal one. Pronotum transverse, moderately flat, with the anterior lobe, omitting the outer margin, very prominently convex, indented, and bounded by an impressed line; surface black, shining, exceedingly minutely punctate, very finely pubescent; the lateral margins white, abruptly recurved along their whole length, and a little concave; posterior margin deeply, concavely sinuated, with a yellow spot each side, and a smaller one in the protracted, obliquely truncated angles; the extreme outer angle with a short tubercular ridge. Antepectus black, broadly margined all around with whitish, minutely punctate and finely pubescent; remaining pectoral divisions dull black, finely pubescent; margined behind and outside with white, and with extero-posterior lobes also white. Coxæ black, terminated and margined with white; femora lineated, with black on the inside and outside, either throughout or in part; the knees and lines upon the tibiæ and their ends, the basal joint of tarsi, and the ends of the second and third joints also black; nails pale piceous. Scutellum black, very minutely punctate, finely pubescent; a short, linear, yellow spot on the margin, at the outer end of the transverse impression, and the acute tip with a more or less slender spot each side. Corium black, finely, closely punctate and pubescent; the costal margin, a longish double spot on the suture a little behind the base, a similar but larger spot on the middle, a third, either double or triple, near the apex, two or three smaller ones near and on the posterior margin, and one near the inner angle of the clavus yellow; the base of the costal margin is less expanded than in the preceding species; membrane blackish, with a transverse series of oblong, pale spots behind the base; the cuneus yellow, but black at base. Venter black, polished, very minutely punctate, remotely, finely pubescent, the segments margined behind and exteriorly with white. Male genital segment very closely set with long bristles, with still longer, very slender, strongly curved appendages, and with two short teeth on the middle superiorly. The other attachments are not disclosed in my specimens.

Length to tip of venter, 4-5 mm.; to tip of membrane, 5½-6 mm. Width of base of pronotum, 2-3 mm.

"A sprightly species, which inhabits dark rocks in the beds of running creeks and brooks in the metamorphic region of Maryland; and of eastern Massachusetts, near Waltham and West Cambridge, from May till October. It flies from rock to rock on such as are not covered by the water, and from its wariness and activity is quite difficult to capture.

"Mr. Kennicott found specimens in Illinois; others have been sent to me from Ottawa, Canada, by Mr. Billings. Mr. Scudder collected it near Lake Winnipeg. Mr. Sanborn met with it on the Magalloway river in Maine, and on a brook near Andover, Mass. The Abbe Provancher sent me specimens from Port Neuf near Quebec, and Mr. Say's came from Indiana."—*Uhler.*

Van Duzee adds Maine, New York, North Carolina, Minnesota and Nebraska.

Genus CHILOXANTHUS Reuter 1895.

"Body wide. Gula of head rather short. Eyes anteriorly less convergent. Ocelli distinctly separated. Interocellar space about as wide as the ocellus, or a little wider. Rostrum reaching to apex of intermediate coxa or a trifle beyond. Pronotum toward apex slightly narrowed, between angles of the apical margins subequal in width to the head. Sides flattened, lateral margins suddenly angulated before the apex, the callus by no means touching the margin. A transverse impression placed behind this, behind the middle of the disc; base of margin broadly emarginate. Interior vein of corium of hemelytra furcate toward apex; branches attaining the suture of the membrane; internal area or first basis produced before the next area, never more than one-third, rarely only one-quarter of its part; the apex by no means reaching the apex of the second. Last ventral segment of female truncate. Type *Acanthia pilosa*."

Chiloxanthus stellata Curtis 1835.

Acanthia stellata Curtis, Ross's Second Voyage to the Arctic Regions, appendix lxxv, Nov. 24.

"Blackish sericeous; elytra with a pale spot at the center and several at the apex; legs ocherous. Black, clothed with very short shining hairs; thorax transverse, the edge beneath subocherous, as well as the center of the antepectus; scutellum rather large; elytra with the costa reflexed at base, a semitransparent spot at the base, another on the disk, and eight or nine arranged in a circle on the submembranous apex; margins of abdominal segments beneath ocherous, and forming a row of dots down each side; legs dirty ocher, somewhat freckled with piceous.

"Length three lines.

"The head is wanting to the only specimen I have seen; it most resembles *A zosteræ* Fabricius, but it is very distinct from my examples of that insect. As some of its larvæ or pupæ were found, it is probably not uncommon in the polar regions."—*Uhler*.

Van Duzee specifies as localities: Arctic America; Pt. Barrow.

Genus SALDA Fabricius 1803.

"Body very broadly obovate or macropterous forms oblong ovate. Head subvertical, partly deflexed below and converging a little anteriorly, gula quite long. Ocelli subcontiguous. Rostrum reaching the middle of the posterior coxæ or little more. Antennæ quite slender, shortly pubescent, longer pilosity sparse. Second segment 2½ or 3 times the length of the first. Pronotum toward the apex quite strongly narrowed. Apical margin narrower than the head, sides straight or rotund. Callus quite large, attaining behind almost a quarter of the basal part. Basal margin broadly emarginate. Veins of the corium joined by an almost obsolete slender litle vein, interior vein furcate toward apex, branches reaching suture of membrane. Embolium entirely black. Membrane often abbreviated. Alæ usually abbreviated or lacking. Third segment of posterior tarsus subequal, length to second. Apex of last ventral segment of female elongated and rotund. Type *Acanthia littoralis* (L)."

Salda littoralis (Linnæus) 1758.

Cimex littoralis Linnæus, Fauna Suec., 246, No. 915; Sys. Nat., 481, No. 14.
Salda littoralis in Fieber, Europ. Hemipt., 147, No. 15.

"Ovate, rather dull black, clothed above and beneath with closely appressed yellow hairs, the head with a few distant, prominent, black hairs. Head moderately long, the eyes very prominent, the face oblique, carrying a few long, erect, black bristles; base of the head constituting a distinct neck, the throat concave; tylus in the middle and the ends of the cheeks generally yellow, but sometimes totally black; front moderately flat, triangularly emarginate at the base of the tylus, the labrum broad,

with the lateral edge sharp, and with a median ridge. Rostrum reaching almost to the middle of the posterior coxæ (in one specimen, not extending beyond the intermediate coxæ), piceous-black, paler or yellowish at tip. Antennæ moderately long and slender, thickly clothed with fine, projecting, black hairs, a few of which are stouter; basal joint yellowish-brown above, dark at base, and beneath, with the basal two-thirds, blackish; second joint slender, dull yellowish, piceous at base and tip, a little shorter than the third and fourth united; third and fourth a little stouter, subfusiform, dusky black, subequal in length. Pronotum subtrapezoidal, the posterior lobe transversely flat, the anterior lobe convex, reaching two-thirds of the length, smooth, bounded by a deeply impressed line each side and behind, its central fovea small; sides flattened, the recurved edge bending abruptly downward before reaching the collum; posterior third of disk finely crenate-punctate. Scutellum finely crenate-punctate, finely rugulose behind, the depression large, somewhat incurved and well defined. Legs dull yellow; the femora with short, yellow hairs, the anterior ones blackish on the outside, and the middle and posterior ones with two rows of brown dots on each of the outer and inner surfaces; tibiæ with short brown hairs and remote stouter black hairs; first and last joints of the tarsi blackish, the second joint and nails dull yellow. The tarsi are often soiled yellow, with blackish hairs, and with only traces of dusky on the ends of the first and last joints. Venter shining black, very minutely rugulose, clothed with fine sericeous, yellowish, prostrate pubescence, the posterior margins of the segments often pale piceous, and apex of the terminal segment yellow.

"Hemeltyra minutely scabrous, golden sericeous, appressed pubescent; generally with an oblong yellow spot near the end of the clavus; corium marked on the disk with a longitudinal series of four long, yellow spots between the first and second nervules, and near the tip with one or two smaller spots placed more inwardly; costal margin broadly arcuated, turned up, the submargin depressed, broader at base; membrane pale brownish or dirty yellow, sometimes short, and almost confined to the inner length of the corium, the cuneus black and coriaceous, inclosing the outer side of the membrane; the areoles with a series of black spots across the middle, more or less blackish at base and tip, and the nervules deep black.

"Length to tip of venter, 5-6 mm.; to end of membrane, 5½-7 mm. Width of base of pronotum, 2-2½ mm.

"Common in various parts of Europe, as well in the North as in the South. In some parts of England, it inhabits the seashore. Specimens from the United States have thus far been collected only in Illinois and Utah."—*Uhler.*

Van Duzee adds: Quebec, New York, Indiana and California.

Salda coriacea Uhler 1872.

Salda coriacea Uhler, Fifth Ann. Rep. U. S. Geog. Surv. for 1871, 1872, p. 421, No. 2.

"Form similar to that of *Salda littoralis* Linnæus, but much narrower, very elongate-ovate, black, highly polished, minutely shagreened. Head oblique anteriorly, distinctly shagreened, sericeous pubescent, the base moderately wide, slightly convex, forming a distinct neck; ocelli honey yellow, lacking the raised chevron in front of them, and having traces only of the oblique grooves and central line; front moderately flat, the tylus prominently raised, polished, bald, cylindrical; the labrum much broader, acutely angular at tip, a little longer than the tylus, and of the same testaceous color, or both black. Eyes large, prominent, brown, placed very obliquely. Rostrum reaching to the posterior coxæ, piceous, paler at base and tip. Antennæ black, remotely bristly, the first two joints often paler above; the basal joint stout, increasing in thickness beyond the base; the second joint more than twice as long as the first, a very little enlarged at tip; the third and fourth longer than the basal,

subequal, the third a little thicker, both slender on the ends. Pronotum subcampanulate, narrow, very much rounded in front, the lateral margins flattened and a little reflexed, but tapering very slenderly in the direction of the collum, before reaching which it turns downward and fades out; the anterior lobe very narrow, but strongly convex, indented on the middle and constricted in front, more or less golden pubescent, and punctate in the depressed lines; the posterior lobe flattened, transversely a little wrinkled, shagreened, and somewhat pubescent; the posterior margin deeply concavely sinuated, the humeral angles produced, broad, flat. Scutellum densely shagreened, sparingly pubescent, a little convex at base, and depressed before the tip. Prosternum either black, or broadly margined each side behind with white, and, together with the disks of all the pleural pieces, pubescent and rugulose. Coxæ terminated with piceous or testaceous, the femora pale piceous or yellowish, darker at the knees, and sometimes with a few brown dots on the sides; tibiæ yellow, infuscated at tip, and with the spines piceous; tips of the tarsal joints dusky or piceous, with the nails paler. Hemelytra highly polished coal-black, remotely set with shallow punctures, faintly golden pubescent, the costal margin strongly arcuated, at base broadly expanded, and a little upturned, the edge recurved, and the area very broad, the upturned margin continued tapering to near the tip of corium; the clavus bounded on the inner sub-margin and outer suture by impressed punctate lines; membrane almost as thick as the corium, black, tinged with piceous, sometimes with about three pale brownish spots in the longer areoles. Venter brilliant black, closely, minutely punctate, coated with sparse, fine pubescence. The hemelytra are wider at base than the pronotum, and they gradually widen in their curve posteriorly.

"Length to tip of venter 5-6 millimeters; to end of membrane 6-7 millimeters. Width of base of pronotum scant to full 2 millimeters. Full width across the corium 3-3½ millimeters.

"The greatest number of specimens thus far acquired have been from eastern Massachusetts. Mr. Sanborn collected several near Andover; Mr. Scudder secured one in the vicinity of Lake Winnipeg; Robert Kennicott found it in British America, near Mackenzie river; other specimens have been sent to me from Northern Illinois; and the Museum of Comparative Zoölogy has specimens from British Columbia, collected July 14. The genital segment of the male is wider than long, almost gibbous, with the central attachments stout, curved toward each, and the exterior appendages long, slender, and overlapping each other when at rest. A specimen, the original type, was taken at Ogden, Utah, and another by B. H. Smith in the region of Denver. The nymph, from Massachusetts, has the usual 2-jointed tarsi, is broader and relatively flatter than the imago, and much resembles, particularly in the form of the abdomen, the common oriental cockroach."—*Uhler*.

Van Duzee adds New York, New Jersey, Maine, and Ontario.

Salda anthracina Uhler 1877.

Uhler Bul. U. S. Geol. Surv. III, p. 438. 1877.

"Form of *S. coriacea*, but still more slender, the pronotum narrower and more convex, and the wing-covers very arched and decurving over the body like the shell of a terrapin. Deep, coal-black, shining. Head moderately narrow, minutely pubescent; the eyes very large, prominent, and oblique; face long, oblique, dull black, rugulose, with the impressed lines faint, and the shield of the vertex obsolete; base of head forming a distinct neck, coarsely shagreened and rugulose, a little flattened on top, rounded off posteriorly. Rostrum reaching to the posterior coxæ, piceous-black, paler at tip. Antennæ stout and long; the basal joint long, black, not much thicker and but little shorter than the third; second about twice as long, yellow, black at base, dusky, and a little enlarged at tip;

third and fourth dusky, subfusiform, stout, the latter a little shorter than the third. Pronotum like the basal half of a funnel, very narrow anteriorly, sparingly sericeous pubescent, finely, obsoletely punctate, and shagreened, the sides anteriorly compressed, the callosities obsolete, the transverse impressed line abbreviated at each end, punctate; the posterior margin concave, with the posterior angles produced, oblique; the lateral submargin a little flattened, coarsely shagreened, the edge reflexed, turned down anteriorly, and thinning out. Pectoral pieces rugulose in part, deep black. Legs yellow, the coxæ black or piceous, with the ends more or less yellow; anterior femora with a few brown dots, tip of tibiæ and last tarsal joint piceous. Scutellum coarsely, irregularly rugose, excepting the apex, which is nearly smooth. Hemelytra of almost equal thickness throughout, very convexly inflated, and decurving on the sides and posteriorly, slightly pubescent, polished, obsoletely, remotely punctate, the punctures of the deep sutures coarse and distinct; the membrane hardly distinct from the corium, the basal thick nervure obsolete. Venter polished, closely golden pubescent.

"Length to tip of venter, 4-6 mm.; to tip of hemelytra, 5½-7 mm. Width of base of pronotum, 1¾-2 mm.

"Inhabits York county, Pennsylvania. Collected by the late Dr. F. E. Melsheimer, and by myself in the neighborhood of his farm."—*Uhler.*

Van Duzee adds New Hampshire.

Genus SALDULA Van Duzee, 1914.

"Body oblong, oval, or sometimes obovate in brachypterous forms. Head subvertical. Ocelli usually very much approximate. Rostrum reaching to middle of intermediate coxæ or posterior coxæ. Antennæ quite slender. Base of pronotum broadly emarginate, other structures very variable. Lateral margins straight or rounded. Callus by no means reaching lateral margin, extending further behind middle of disc. Scutellum longer than broad, impression far removed from base. Hemelytra often variegated with silky black patches—Membrane furnished with four areas, more or less explicate or abbreviated, in this case attaining apex of abdomen. Third segment of posterior tarsus a little longer than second—Apex of last ventral segment of female produced and rounded. Type, *Acanthia saltatoria* L."

Saldula major (Provancher) 1872.

Provancher Nat. Can., p. 107, 1872.

"Oval, robust, dull black, the upper surface remotely appressed, golden pubescent, and with a few erect, remote brown hairs. Head from above short and blunt, minutely, densely scarbrous, the base forming a neck, a little convexly elevated, the eyes moderately prominent, brown; front almost vertical, a little oblique, closely golden pubescent, triangularly depressed before the ocelli, the face a little flattened; tylus much shorter than the labrum, they and the ends of the cheeks and bucculæ sometimes yellowish. Rostrum generally reaching upon the base of venter, but sometimes a little shorter, piceous-black, becoming yellow at tip. Antennæ very slender, black, pubescent and setaceous; the basal joint above and the second joint excepting the tip sometimes dull yellow, the former very short, not as long as the eye; second joint about twice as long, slender, much shorter than the last two united; third and fourth subequal, very slightly thicker than the second, a little subfusiform. Pronotum semilunate, short, depressed, dull black, minutely shagreened, but with the broad, thin, depressed lateral submargins more coarsely so, the margin a little turned up, but not abruptly reflexed; anterior lobe defined by a lunate, impressed, punctate line, hardly elevated, longer than the posterior lobe, and with a deeply indented point in the center; humeral angles broad, moderately prolonged, with a long tubercle next

the outer angle; posterior margin deeply concave; the anterior angles rounded off, and the anterior margin with a narrow collum. Prosternum and pleuræ shining black, golden pubescent, somewhat rugulose in places, very minutely scabrous. Legs black or soiled yellow, pubescent, and with some long erect hairs intermixed; the femora when yellow more or less black beneath, and dotted with piceous on the two sides; tibiæ dull yellow, piceous at base and tip, with the spines piceous; tarsi soiled yellow, with the basal and apical joints or their apices piceous; nails very pale piceous. Scutellum large, almost flat, slightly depressed on the disk, densely scabrous, and on the apical part a little rugulose. Hemelytra dull black, almost flat, densely shagreened, and depressed golden pubescent; costal margin expanded and arcuated at base, the lobe upturned, and rapidly tapering to a termination behind the middle; corium marked with short, white or yellowish, linear spots, of which two are on the inner line of the costal area, a longitudinal series of about four near the outer side of the discoidal area, and two or three on the inner area, and a small spot near the inner angle of the clavus; membrane soiled white or yellow, with a cloud at base and tip, and about two transverse series of fuscous oval spots in the areoles, sometimes with the apexes of the areoles more or less blackish, the nervules blackish, and the outer areole broad-triangular. Venter short and broad, shining black, closely and finely clothed with prostrate yellowish pubescence.

"Length to tip of venter, 4½-6½ mm; to tip of membrane, 8 mm. Width of base of pronotum, 2½-3 mm.

"Inhabits Maine, Massachusetts, New York and Maryland, in September; Texas, New Mexico, Missouri, Illinois, Michigan, Minnesota; Mackenzie river region, Robert Kennicott; Canada—near Saskatchewan river, and in the province of Ontario.

"Specimens occur which are destitute of white spots upon the corium and clavus. I found numerous specimens upon the mud of the black marshes of Brighton and Cambridgeport, Mass., in the month of July.

"The remarks under *S. lugubris* Say, in my paper printed in Dr. Hayden's Bulletin, vol. II, Nov. V, p. 67, belong to this species."—*Uhler* as *Saldula deplanata.*

Van Duzee's catalogue adds Quebec, Rhode Island, New Jersey, Pennsylvania, Wisconsin and Kansas.

Parshley adds New Hampshire.

Saldula confluenta Say 1832.

Acanthia confluenta Say, Heteropt. New Harmony, 25, No. 5.
Acanthia confluens Say (emend, Le Conte), Complete Writings, I, 361, No. 5.

Black; membrane of the hemelytra with a blackish band. Antennæ pale at base; head and thorax immaculate; corium with a large marginal spot before the middle, and another at tip, two small spots; membrane with fuscous nervures and a continuous, blackish, arcuated band on the middle; feet whitish, tarsi with blackish tips; thighs with an obsolete brown line; venter whitish at tip.

"Length to tip of hemelytra one-fourth of an inch.

"Inhabits the United States.

"The band of the membrane does not reach the inner margin. It is equal in size to *A. ligata.*"—*Uhler* as *Salda confluens.*

Van Duzee's catalogue lists Quebec, New York, New Jersey.

Saldula orbiculata Uhler 1877.

Uhler Bul. U. S. G. G. Surv. III, p. 450, 1877.

"Almost circularly ovate, deep dull black when invested with the clothing, but shining black when rubbed; the upper surface invested with long, erect, golden and blackish, almost matted pubescence. Head wide, from above blunt and short; the front almost vertical, a little curved,

clothed with erect black hairs and prostrate golden pubescence; front a little flattened; vertex with an indented point each side near the eye; ocelli small, pale piceous; base of head smooth, not obviously punctate, a little convex, forming a moderate neck; tylus very slightly prominent, shining, pale fulvous; lower edge of the clypeus fulvous, very slenderly recurved; labrum broad, fulvous, invested with pale yellow bristles. Rostrum testaceous, reaching upon the posterior coxæ. Antennæ short, moderately slender, the basal joint short and stout, testaceous; the second quite slender, pale piceous, testaceous at the base and piceous at tip, about twice as long as the basal one; it and the following joints with remote erect hairs; two last joints subequal, long, subfusiform, blackish, longer than the basal joint. Pronotum transverse, contracted at the column, flattened, the sides oblique but arcuated, with the submargin moderately broadly flattened, of almost uniform width throughout, a little upturned, thick, a little turned in and widened at the poserior angles; posterior margin moderately deeply concave, the humeral angles produced, broad, short, scooped out; anterior lobe with the callosities feebly elevated, but not nearly extending to the lateral margin, the transverse line deeply seated; posterior lobe about one-third the length of the anterior one, indistinctly rugulose. Scutellum not distinctly punctate, short and wide, deeply lunately impressed on the middle, the surface beneath the dense pubescence polished, jet-black. Sternum jet-black, polished, finely whitish pubescent, the pieces of the mesopleura more or less white. Coxæ piceous, paler at the tip; legs pale orange or fulvous, the spines and extreme tip of the tibiæ, the basal joint of tarsi, the end of the apical joint, and the nails piceous. Hemelytra flat, disk-like, the costal margin almost semicircular, narrowly flattened and upturned, pale yellow, not wider at base; corium velvety-blackish, densely coated with prostrate golden pubescence and with longer blackish hairs; costal area very wide, with a testaceous spot on the middle entering from the outer margin, and a similar one before the tip; nearly one-half of the posterior margin running from the outer angle testaceous, and the inner edge of the clavus very narrowly of the same color; disk with about four round bluish spots, and a similar spot near the apex of the clavus; membrane fuscous, a spot at the inner angle, the inner margin, the posterior submargin, and an apical spot, four spots on the bases of the areoles, and four near their tips pale testaceous. Venter black, terminated with white, and closely invested with prostrate whitish pubescence.

"Length to tip of hemelytra, 3½-4½ mm. Width of base of pronotum, 1½-2 mm. Width across hemelytra, 2-2½ mm.

"This neat and unusual form of Salda has a very wide range of distribution. It occurs in Eastern Massachusetts, Pennsylvania, New York, Illinois, and Texas, and the Museum of Comparative Zoölogy has specimens from Calaveras and San Diego, Cal."—*Uhler.*

Van Duzee adds Ohio.

Saldula explanata Uhler 1893.

Uhler, Proc. Ento. Soc. Wash., II, p. 383, 1893.

"Subelliptical, deep dull black, but lustrous when the surface is rubbed. Similar to *S. brachynota* Fieber of Europe, but the pronotum is broader than in that species, and there is an absence of white marking on the basal part of the costa. Head and antennæ black, the latter sometimes piceous at base; the rostrum piceous beyond the base, reaching to the posterior coxæ. Pronotum nearly lunate, not deeply but broadly sinuated, with the humeral ends as wide, flat, rounded lobes, the lateral margins moderately curved, prominently reflexed, with the submargin concurrently broadly sulcated. Hemelytra a very little wider than the pronotum, with the costa wide, and acutely reflexed, corium with two or three small groups of obsolete pale specks; membrane with the areoles pale, and each marked in the middle with a black dot. Tibiæ pale piceous on the middle.

"Length to tip of membrane, 4½-5 mm.; width of pronotum, 2 mm.
"Specimens were secured at City Canon, June 26, and also at Ogden and Alta."—*Uhler.*

Van Duzee adds Idaho, California and Vancouver Island.

Saldula dispersa Uhler 1877.

Proc. Ento. Soc. Wash., 11, p. 383 (1893).

"Very closely related to *S. pallipes* Fabricius of Europe, and having the white marks of the hemelytra essentially the same as in that species. The general form is also the same, but the pronotum is a little narrower, with the lateral margins less curved, almost directly oblique. This insect varies so much in the amount and distribution of the white marking of the hemelytra that no satisfactory definition can be given of its ornamentation. In general, however, it may be seen to have a broad black band across the base of the hemelytra connecting with the continuous black clavus, and thus forming the inner boundary of the large white spot behind the base of each corium. Behind this spot are several others of smaller size; the membrane has four pale cells, in each of which there is often a black streak. The cheeks are usually white, as is also the lower part of the tylus, and the inner side of the basal joint of the antennæ.

"Length to tip of membrane, 3¼-4½ mm.; width of pronotum, 1¼-2 mm.

"A few specimens have the tibiæ pale testaceous, with black knees and tip, and with dark spots at variable intervals.

"Numerous specimens were secured at Salt Lake from June 13 to 25. Others were sent to me from various parts of Utah, and I found the species to be comparatively abundant in various places west of Denver, Colorado."—*Uhler.*

Van Duzee adds California.

Saldula interstitialis Say 1825

Acanthia interstitialis Say, Journ. Acad. Phila., IV, 324, No. 1.

"Ovate, dull black, closely bronze pubescent, with a few remote, erect black hairs on the head, pronotum, and base of the hemelytra. Head from above broad and short, vertical, with a very short neck behind; the eyes large, brown, moderately projecting above the line of the vertex; base of head moderately convex, minutely shagreened, separated from the ocelli by a transverse impressed line; front almost flat, densely, minutely scabrous, the longitudinal groove obsolete; reflexed edge of the clypeus yellow or piceous; tylus a little prominent, slightly narrower inferiorly, yellowish, a little shorter than the labrum, bald; labrum broad, yellow, a little ridged on the middle line, with the sides sloping, the tip bluntly triangular and set with stiff hairs. Upper margin of the bucculæ yellow; rostrum reaching behind the end of the posterior coxæ, dark piceous, paler at tip. Antennæ slender; basal joint short and stout, dull yellow, with a black line beneath and sometimes obscure on the middle above; second joint a little shorter than the third and fourth conjoined, yellowish or pale piceous, darker on the middle, slightly thickened at tip; third and fourth subequal, dull black, each longer than the basal one, and stouter than the second, subfusiform. Pronotum lunate, densely coated with prostrate golden pubescence and with longer black hairs on the margins and before; lateral margins moderately and abruptly reflexed, the submargin broadly depressed, of uniform width throughout, minutely scabrous; surface generally minutely scabrous; the callosities forming a transverse ridge, sharply bounded by an impressed punctate line, which curves around the sides and stops at an indented point some distance behind the anterior margin; posterior margin deeply concave, the lobed humeral angles obliquely truncated and with a long tubercle near the

outer corner. Scutellum feebly convex, closely minutely scabrous, lunately impressed, the apical division a little flattened, obsoletely rugulose, with the edge yellowish. Pectoral pieces polished, black, clothed with prostrate whitish pubescence, the prosternum slenderly margined with white. Legs dull yellow, generally with a black line on the under side of the femora and tibiæ; the femora often with piceous dots on the front and back faces; tibiæ tipped with piceous, with piceous spines, and sometimes with piceous spots or faint bands at the base of the spines; tarsal joints tipped with piceous and the basal joint entirely piceous, the nails pale piceous. Hemelytra black, almost flat, minutely scabrous, with close, appressed, golden pubescence, and with longer, remote, black hairs exteriorly and basally; the costal margin moderately arcuated, with the edge abruptly, narrowly recurved, and black or rarely piceous; corium with four or five whitsh oblong spots, of which there is a double one on the costal area behind the middle and a similar one near the tip, a large central one on the discoidal areole and a smaller one farther back; and at the tip of this areole, on the suture, is a larger triangular spot, or very small white spot behind a velvety-black one near the tip of the clavus; membrane dull whitish, dusky at base and tip, with black nervules, and across the middle a series of oblong, blackish spots. Venter black or tinged with piceous (or sometimes pale brownish); the apical segment entirely, or only a broad margin, whitish.

"Length to tip of venter, 3-4 mm.; to tip of membrane, 4-5 mm. Width of base of pronotum, 1¾-2¼ mm.

"Inhabits Missouri, Mr. Say. Specimens in my own collection were taken at Saint Joseph, Mo., by Mr. E. P. Austin; by myself at Andover, Mass.; and near Baltimore, on the dark sand of a loamy spot near a brook, in May and June; also in Dakota, Nebraska, and Illinois. Some variation occurs in this form. such as the greater expanse of the white spot upon the apex of the corium, and of the pale colors of the prosternum and legs."—*Uhler*.

Van Duzee adds: Quebec, Ontario, Maine, New York, New Jersey, Pennsylvania, Florida, Indiana, Michigan, Colorado, Texas, New Mexico, Idaho, and California.

Saldula separata Uhler 1878.

Uhler, Proc. Bost. Soc. Nat. Hist., XIX, p. 432, 1878.

"Black, minutely, sparingly pubescent above; general form of *S. interstitialis* Say. Head large, eyes brown, large and very prominent; face minutely, densely punctured, clothed with erect hairs; cranium wider than in the preceding species, having a small yellow spot each side against the eyes, on a line with the amber-yellow ocelli; lower margin of the clypeus recurved, the tylus and labrum bright yellow, the rostrum, excepting its immediate base, piceous, extending a little beyond the base of the posterior coxæ. Antennæ black, the basal joint yellow, black underneath excepting the base and tip; the second joint almost twice as long as the basal, third longer than the basal and shorter than the fourth. The base of head longer than in the preceding species. Pronotum obsoletely punctured, hardly polished, clothed with erect pubescence; the sides oblique, slightly curved, the callosities more polished, connate, forming a single transverse elevation, with a rounded pit in the middle; behind it is an impressed, punctured line. Pectus polished black, obsoletely wrinkled, sparingly pubescent. Legs testaceous; the coxæ more or less infuscated; anterior femora black on the middle underneath, the intermediate and posterior pairs with a black spot beneath near the tip, and clothed with thick, whitish pubescence; tip of tibiæ and also of tarsi blackish. Hemelytra dull black, obsoletely rugulose, sparingly clothed with erect pubescence, widest just behind the middle; the corium with a yellow dot on the exterior margin near the tip, usually also with three or four more minute ones on the middle suture and one at tip of clavus. Membrane sometimes

whitish, with a large black spot at the base inwardly, a small subquadrate one against the base exteriorly, and behind this an orange spot which is bounded behind by another black spot; the nervures blackish. Others have the membrane black, with a yellow spot against the exterior margin and a few pale vestiges on the middle. Venter, black, more or less tinged with piceous, polished, very remotely pubescent, minutely inconspicuously punctured, tip of the genital segment broadly white. Length, 4-4½ mm. Humeral breadth, 1½ mm. Extreme width of hemelytra, 2 mm."—*Uhler*.

Distribution: "Canada, New Hampshire, Massachusetts and Pennsylvania."—*Van Duzee*.

Parshley adds Vermont.

Saldula reperta Uhler 1877.

Uhler, Bul. U. S. G. G. Surv., III, p. 447, 1877.

"Closely resembles *S. marginalis* Fallen. Deep, dull black, sparsely clothed with golden prostrate pubescence, and the head and pronotum with a few erect black hairs. Head above broad and blunt, the base forming a short neck; the surface minutely scabrous; eyes prominent, brownish, moderately oblique; front moderately narrow and flat, not distinctly arched at base; the lower margin of the clypeus callous, feebly recurved, testaceous, black in the center; tylus and labrum forming an arched bridge, dull ocherous, the former a little concave on the sides inferiorly, the latter piceous at tip and a little pubescent. Rostrum reaching upon the intermediate coxæ, dark piceous, paler at tip. Antennæ moderately stout, clothed with pale, stiff hairs; basal joint dull yellow, black beneath; second piceous, paler at base and tip, not twice as long as the basal one, and a little thickened at tip; third and fourth dull blackish, subfusiform, subequal, each longer than the basal one. Pronotum transverse, subtrapezoidal, rather flat, with the sides very oblique, hardly curving; the submargin broadly depressed and gradually narrowing toward the front; the callosities feebly elevated, deeply and broadly foveate in the center, bounded by a deeply impressed line; the surface minutely and densely rugulose; posterior margin very slightly concave, with the humeral angles moderately produced, very broad, and with a large, low fold near the outer angle. Scutellum scabrous at base, minutely, transversely wrinkled on the apical half; the central impression lunate, distinct. Legs dull testaceous, very hairy, more or less marked with piceous on the femora, particularly beneath, on the tibiæ, somewhat in spots, the tips, spines, and the basal and apical joints of the tarsi piceous-black, the nails dull testaceous. Sternum and under side of the body shining black, minutely, closely whitish pubescent; the extreme edge of the prosternum and of the ventral segments and a broad end of the genital segment of the female whitish. Hemelytra deep black; the corium closely yellow and black pubescent, densely shagreened, the costal margin moderately arcuated, broadly and continuously flattened, recurved from the base to behind the middle; the costal area with a testaceous small spot behind the middle and two smaller parallel ones near the tip, the middle nervure with a spot near the base, and the middle areole with a larger spot at tip and two or three smaller ones near the tip; the clavus with a small yellow spot near the tip; membrane dull white, fuscous at base and with a broad cloud at tip, a transverse series of oblong fuscous spots across the middle and a spot at the tip of the exterior areole; the nervures piceous or black.

"Length to tip of hemelytra, 4-4½ mm.; to tip of venter, 3½-4 mm. Width of base of pronotum, 1½ mm.

"A few specimens from the Museum of Comparative Zoölogy, collected in Cambridge, Mass.

"This is a robust little species, very closely related to *S. interstitialis* Say, and perhaps only a variety of it. But the different shape of the pronotum, with the other details, will at present serve to separate it."—*Uhler*.

Distribution: Quebec, New Hampshire and Massachusetts.

Saldula xanthochila Fieb. 1859.

Fieber, Wien Ent. Monat., III, p. 234 (1859).

"Marginal line black like the pronotum. Outer basal angle of the membrane with short black cross stripes on the angle of the corium. Cells of the membrane with elongate dots or spots. At the end of the first cell a smaller square blackish spot. Sides of the pronotum straight. Corium somewhat broadened behind, on the median field on the principal vein with four small whitish spots; outwardly two elongate white spots, at the angle of the corium with two larger spots, sometimes confluent. Tip of clavus with roundish spot. Antennæ black. First segment yellow, black beneath. Base of rostrum and legs yellow. Femora black beneath with a semicircle on the end. Tibia at base and tip, and first and third tarsal segments, black. Length two lines. Often confused with *S. saltatoria*."

Distribution: New York, New Jersey, Colorado, Utah, Nevada and California.

Saldula xanthochila var. limbosa Horv. 1891.

Horvath, Revue d' Ent., p. 80, 1891.

"Size smaller. Lateral margins of pronotum broadly margined with pale. This pale margin about subequal to the fore femora. Spot at base of corium smaller. Length, 3 mm."

"Differs from the type only by the yellow border of the pronotum being broader. The size much smaller, and the black spot at base of the corium less developed."

Found in New Jersey and Florida.

Saldula pallipes Fabricius 1794.

Salda pallipes Fab., Syst. Rhyng., 115, No. 12. H. Schf., Wanz. Ins., VI, fig. 600.

"Moderately long-oval, thickly clothed above with appressed golden pubescence, and fringed with almost erect pile. The head, fore part of the pronotum, and basal parts of the hemelytra with erect black hairs. Head from above short and blunt, the front nearly vertical, dull black, moderately flat, minutely granulated, clothed with appressed golden pubescence and some longer black erect pile; inferior margin of clypeus emarginated in the middle, thick, elevated into a slight ridge, yellow, smooth; tylus a little prominent, bald, narrowing inferiorly, and, together with the labrum, reddish-yellow; the latter a little longer, pubescent, infuscated at tip; rostrum reaching to the tip of the middle coxæ, piceous; antennæ black, with short hairs; the first and second joints more or less fulvous, black above and beneath. Ocelli black. Pronotum very transverse, minutely scabrous, the sides arcuated, flattened, the edge a little reflexed; the posterior margin very concave, across the scutellum; the humeral lobes roundly produced; callosities occupying half the length, moderately prominent, the central fovea deep and transverse, the side impressions obsolete, the bounding furrow deep; scutellum convex, the central depression deep, sharply defined behind; the base finely scabrous, the apical half rugulose. Hemelytra slightly convex; clavus black, the apex with a large or small wedge-shaped yellow spot; corium black at base, sharply distinguished from the rest of the pale yellowish surface; the basal one-third of the costal margin rounded and a little broadly expanded and turned up, the margin black, and with a black spot at the apex; costal area with two long contiguous black spots, nearly forming a black streak, the second interrupted by a white dot; between the first and second nervures basally a black spot, with a broad ring of the ground-color around it; below this ocellus is a black spot; at the end of the second nervure is another black spot, sometimes extended to the inner

angle; and beyond this nervure, on the disk, is a long black spot; nervures black, sometimes pale posteriorly, and occasionally destitute of the intervening black spots; membrane pale yellowish or white; the nervures piceous or black, excepting the exterior one, which is generally pale, with a black spot at its tip; across the middle is a series of oblong spots, and sometimes a larger one near the base of the third cell, the apical margin generally infuscated; sternum black, the prosternum slenderly margined behind with yellow; legs yellow, with fine, short, yellow hairs; the femora having two rows of brown points on the inner and outer faces, the under side with a blackish streak; tibiæ with black spines and apex, the anterior pair with a blackish line on the under side; apex of the last tarsal joint black, the nails pale brown; abdomen black or blackish, the posterior edges of the ventral segments whitish, that of the apical segments broadly whitish.

"Length, 3-5 mm. Width of pronotum, 1¼-1½ mm.

"Dr. Stal reports this species to have been taken in Sitka. Specimens belonging to the Museum of Comparative Zoölogy, kindly sent to me for study by Dr. H. A. von Hagen, were taken at San Diego and Bard's Ranch, Cal. These specimens are larger than those from the Rocky Mountain region, of which many have passed through my hands, from various localities in Utah, New Mexico, etc. In the western suburbs of Denver, Colo., it may be met with in untold numbers on the dark, damp, sandy, and muddy soil, during the month of August. A few specimens occurred to me on dark, damp soil, next the stream of water running down the Beaver Brook Gulch, and also in similar spots in Clear Creek Canon. I can find no characters to separate it from specimens which I collected in Hayti on the marshy banks of the Grand Anse river in May, nor from Cuban specimens received from Professor Poey. It occurs also in New Jersey and on the dark mud of the sea coast of Maryland.

"Dr. Packard collected it near Georgetown, Colo., July 8, at an elevation of 9,500 feet, and also near Salt Lake, Utah, July 27."—*Uhler*.

Reported also from New York, Ontario and Nevada.

Parshley adds Maine, New Hampshire, Vermont, Rhode Island, Connecticut and Massachusetts.

Saldula laticollis Reuter 1875.

Reuter, Pet. Nouv. Ent., I, p. 544, 1875.

"Similar to *S. saltatoria* and referrable to the same division, but much larger, pronotum strongly transverse, with an arcuate impression and a profound foveola on the disk. Middle of the sides straight. Hemelytra marked as in *S. saltatoria*, but the external margin of the corium with a large single spot (often paired) situated immediately behind the middle. Length, 4.75 mm."

Saldula sphacelata Uhler 1877.

Uhler, Bul. U. S. G. G. Surv., III, p. 434, 1877.

"Elliptical, dusky, testaceous, dull, clothed above with minute, close, appressed, fuscous pubescence. Head stout, obliquely curving, almost vertical, pale tawny, inscribed with black on the vertex and with a black spot behind, the base convex; clypeus longitudinally indented at the base of the tylus; front with an indented, oblique, brown line each side, and the usual impressed line in the middle; basal margin of the eyes and an impressed line bounding the quadrangular bed of the ocelli blackish; ocelli honey-yellow. Rostrum reaching upon the base of the posterior coxæ, slender, yellowish, becoming piceous toward the tip. Antennæ stout, setose, pale flavo-piceous, more or less dusky, particularly on the last two joints, the basal pale, short, thickened toward the tip; second joint very long and slender, faintly thicker at tip; fourth much longer than

the basal and a little shorter than the third. Pronotum transverse, closely punctate, short, the sides very oblique, broadly reflexed; the anterior margin truncate, with a slender collum extending along its entire length, the anterior angles rectangular; the posterior margin concavely a little sinuated, with the outer angles moderately lobed, truncated at the end, and a little folded, and bounded on the inner side of the fold by an impressed short line; the anterior lobe moderately convex, variegated with black, transversely impressed, and with a few coarse punctures in the impression; the impressed line environing the lobe sharply defined, brown, and set with small punctures. Prosternum whitish, a little inscribed with piceous, finely sericeous pubescent; mesopleuræ black, sericeous pubescent, more or less bounded and invaded with tawny; metapleuræ tawny, sericeous pubescent. Coxæ a little piceous at or near the base; legs tawny; the femora more or less dotted with brown, pubescent; the apex and spines of the tibiæ and the ends of the tarsal joints dark piceous; nails pale piceous. Scutellum finely, closely punctate, yellow, blackish on the base and disk, finely sericeous pubescent. Corium pale, dull clay-yellow, remotely sericeous pubescent, paler at base and tip, a little more coarsely punctate; the costal margin broadly arcuated at base, the expansion there wide and thin; costal area broad, pale, infuscated on the inner side, sutures, and nervures; centers of a few of the outer, discal, and apical areoles whitish, with dusky nervules; the clavus dusky; membrane pale, dull testaceous, with strong, slightly curved, piceous nervules, inclosing five long areoles. Venter pale, obsoletely punctate, closely invested with pale, minute, prostrate pubescence.

"A varity of the male is more dusky on the hemelytra, has the disk of the venter (excepting the edges of the segments) piceous, and irregular series of brown dots on the sides. The male genital segment is long, semi-oval, densely set with long hairs.

"Length to tip of venter, 4-5 mm.; to tip of membrane, 5-6 mm. Width of base of pronotum, 1¾-2 mm.

"This species is exceedingly abundant on the discolored sandy and marshy brown spots of the tide-water districts of eastern Massachusetts and Maryland. Some of these tracts of country are no longer within the reach of the tide, although they were at a former period; but still these insects remain there, although apparently in diminished numbers. The salt mud seems to afford them the conditions best suited to their development, and on such spots they may be found in all stages of development and in unnumbered multitudes. As far as I was able to collect them (which was difficult because of their activity and close resemblance to the soil), I found the males to be in the proportion of two to fifteen females. Yet I do not think that this would be the full proportion if we were able to collect them exhaustively over a locality in which they occurred of average abundance."

"Specimens were collected by me at Newtonville, Chelsea, Lynn, and Braintree, Mass., in July; also on Sinepuxent Beach, Maryland, in July and August.

"Specimens have also been found in Cuba, by Prof. Felipe Poey, which were smaller than the average of those from the United States.

"An individual from San Diego, Cal., has the scutellum black, excepting only some small marks of yellow on the sides, and the punctures of the scutellum are coarser than those of the pronotum. Its length is only 4½ mm. and the width of the pronotum is 1¾ mm."—*Uhler*

Parshley adds Maine and Rhode Island.

Saldula opacula Zett. 1840.

Zetterstedt, Ins. Lapp., Column 268, 1840.

"Elongate oval, black, sides of the thorax widely impressed. Scutellum and clavus with golden hairs, the latter with an obscurely pale spot near the apex. Corium with a few obscure pale markings; lateral margin,

except at the base and extreme apex, narrowly testaceous; membrane obscure, its outer margin testaceous; nerves black; legs testaceous; apex of tibiæ and tarsi black; antennæ obscure.

"Length, 1½ lines."

Parshley: Maine and Massachusetts.

Saldula scotica Curtis 1835.

Curtis, Brit. Ento., XII, pl. 548, 1835.

"Black, covered with black semi-erect hairs, and short, pale, appressed pubescence. Thorax with the sides straight. Elytra with the sides gently rounded; disk of each with several pale, roundish spots, varying much in number, and often entirely obliterated; membrane dark, the nerves black. Legs black, a line along the top of each thigh, a band above the apex of each tibia, and the second joint of the tarsi, pale. Antennæ black.

"Length, 2¾ lines."

Saldula pellita Uhler 1877.

Uhler, Bul. U. S. G. G. Surv., III, p. 433, 1877.

"Broad, ovate, dull ochreo-testaceous or clay-yellow, above clothed with erect, moderately long, close, fuscous pubescence, which is longer on the head and margins of the pronotum. Face longer, more oblique and less vertical than in *S. sphacelata*, the front less prominently convex, and the sutures not so distinct; vertex either dusky, or with a small, black spot on the middle, and with a narrow black base; its surface very flat and the eyes very large and prominent; the base of the head forming a distinct neck, which is broader than the diameter in front of the eyes. The tylus pubescent but the cheeks and gula bald and whitish. Antennæ long, dusky, beset with long, dark, hairs; the two first joints clay-yellow; the basal one stout, short, a little thicker toward the tip, second longest, feebly thickened on the extreme tip; third and fourth scarcely thinner than the second, the fourth a little shorter than the third, but not much longer than the basal joint. Rostrum reaching near to the middle of the posterior coxæ, pale at base, piceous at tip. Pronotum polished, transverse, clothed with long, erect, dusky pile, remotely punctate; the lateral margins oblique, with the edge broad, thin, recurved; the anterior angles blunt, but almost rectangular; the collum slender but distinct, blackish; anterior lobe high, very convex, dusky in front, and bordered by a deeply impressed, piceous line, having a few coarse punctures across the middle, and remote finer punctures in the impressed lines; pleuræ pale, finely sericeous pubescent; sternum paler, bald, darker posteriorly; the impressed arc in front of the anterior coxæ piceous. Coxæ pale yellow; legs dark luteous, with dusky hairs; thighs somewhat pointed with brown; the tibiæ with a piceous tip and spines, and the tips of the tarsal joints piceous, the nails paler piceous. Scutellum a little convex at base, polished, pubescent, a little punctate on the base and middle, which are also more or less infuscated. Corium broad, pale luteous, closely, obsoletely punctate, erect, pubescent; the base of costal margin expanded and broadly rounded, the costal area very wide, the sutures and outer margin brownish; membrane paler, the nervures long and rather straight, piceous, bounding five large areoles. Venter highly polished, clothed with long, pale pubescence, minutely and obsoletely punctate. The membrane is not conspicuously distinguished at first sight from the corium, and the latter when held up to a strong light appears flecked and dotted with brown. The disk of the venter is occasionally a little infuscated. Male genital appendages apparently like those of the preceding species. Occasionally there is a series of brown dots on the venter near the connexivum.

"Length to tip of venter, 4-5 mm. Length to tip of membrane, 5½-6¼ mm. Width of base of pronotum, 1½-2 mm.

"Very abundant near the sea coast of eastern Massachusetts. Near Chelsea, July 9; and near Charles river, in the vicinity of Newtonville.

"The posterior angles of the pronotum are obliquely protracted, flattened, obliquely truncated, and with a slight convexity next the outer angle."—*Uhler.*

Saldula lugubris Say 1832.

Acanthia lugubris Say, Heteropt. New Harmony, 34, No. 3.

"Body black, subopaque. Head between the antennæ with three yellowish points; antennæ, first and second joints dull yellowish before. Thorax and scutel immaculate. Hemelytra immaculate on the corium, or with an obsolete dull yellowish point on the middle of the tip; membrane with two or three obsolete dull yellowish spots, inner margin and tip. Beneath with a yellowish spot before each of the anterior feet. Feet pale yellowish; tibiæ and tarsi more dusky; thighs, particularly the anterior and posterior pairs, with a more or less dilated black line toward their tips; coxæ black, the anterior pair yellowish at tip, remaining pairs slightly tipped with yellowish.

"Length to tip of hemelytra, less than three-tenths of an inch.

"For this species I am indebted to Nuttall, who obtained it in Missouri."—*Uhler.*

Saldula elongata Uhler 1877.

Uhler, Bul. U. S. G. G. Surv., III, p. 448, 1877.

"Long-elliptical, narrower anteriorly, dull black, clothed above with prostrate yellowish pubescence, and with a few erect black hairs on the head and pronotum. Head dull black, front very oblique, long and moderately narrow, convex, forming an 8-sided tablet, which is bilobed above, grooved down the middle, and with the lower side-margins of the clypeus a little carinated, black; an oblong callous spot each side next the eyes yellow; tylus smooth, black, yellow at tip; labrum piceous, pubescent, yellow along the middle line; eyes brown, oblique, and very prominent; base of head convex, forming a rather long neck, densely, minutely granulated; tip of the lower cheeks orange; bucculæ and throat dull black, minutely scabrous and whitish pubescent. Rostrum reaching behind the intermediate coxæ, blackish-piceous, paler at tip. Antennæ slender, as long as from the tylus to tip of clavus, piceous; the basal joint stouter, fulvous at tip; the second very long, much more than twice the length of the first, pubescent; third and fourth dull black, pubescent, slenderly subfusiform, subequal, each about two-thirds the length of the second. Pronotum subcampanulate, transverse, densely clothed with prostrate golden pubescence, the anterior part very narrow, with the sides steep, the callosities prominent, convex, rugose, deeply indented on the middle and obliquely so each side of it; posterior lobe about one-half as long as the preceding, deeply, squarely sinuated, the humeral angles obliquely prolonged, flattened, longitudinally sulcated, rugose; the sides broadly flattened, tapering anteriorly, the margin abruptly recurved, and fading out next the collum. Pectus polished black, finely, prostrate, whitish pubescent; prosternum very slenderly margined with white. Legs dull testaceous, the femora more or less piceous beneath and on the front and hind surfaces; tibiæ with piceous knees, spines and tip; tarsi dull testaceous, the basal and apical joints piceous, the nails dull testaceous. Scutellum coarsely, densely scabrous on the prominent base, the impression very distinct, arcuated; the apical division transversely rugulose. Hemelytra narrow, thin, very minutely scabrous, with a very few coarse punctures on basal and costal areoles; clavus black, golden pubescent, having a few coarse punctures and a wedge-shaped yellow spot next the tip, placed on a velvety-black spot; corium yellowish, the costal margin broadly arcuated, the base broadly flattened and turned up, the edge black; costal area broad and long, the base blackish, the middle with a quadrate spot, and near the tip a

roundish one; nervures coarse and deep black; the inner areole black, with two yellow small spots next the outer margin and before the apex, and with a larger one at the inner angle; the central areole black at base, next a large yellow spot, and then black with three moderately large yellow spots, the last one is separated from the apical margin by a black line; membrane pale yellowish, blackish at base, with black nervules margined with blackish, and spots at their tips; a marginal blackish line on the apical two-thirds of the outer nervule, and with a transverse series of streaks; oblong spots on the middle of the areoles. Venter black, minutely sericeous pubescent; the middle of the disk and the posterior part of the genital segment yellowish; posterior margin of the segments pale piceous.

"Length to tip of venter, 5 mm.; to tip of hemelytra, 6 mm. Width of base of pronotum, 2 mm.

"One female, the type, is the only specimen that I have seen. It is from British Columbia, and belongs to the Museum of Comparative Zoölogy. It seems to be closely allied to the European *S. latipes* H. Schf."—*Uhler.*

Saldula luctuosa Stal 1858.

Salda luctuosa Stal, Eugenies Resa, Hemipt., 263, No. 123.

"Oval, blackish, moderately polished, having the form of *S. pallipes*, but the colors and markings similar to *S. littoralis.* Head black, clothed with fuscous hairs, with eyes somewhat broader than the anterior width of the pronotum; eyes moderately prominent. Antennæ somewhat more than half as long as the body, blackish-fuscous. Rostrum blackish. Pronotum three times as wide as long, anteriorly about one-half as wide as at the base, the posterior margin broadly sinuated, the sides scarcely arcuated with the margin, slenderly reflexed; blackish, clothed with somewhat depressed fuscous pile; the anterior lobe a little elevated. Scutellum blackish. Hemelytra blackish, sparingly clothed with prostrate pubescence, the costal margin at base somewhat expanded; membrane very distinct, infuscated, having four areoles. Beneath blackish. Legs obscurely fusco-testaceous, the tibiæ and tarsi somewhat paler, the former sparingly bristly.

"Length, 4 mm. Width of pronotum, 1⅓ mm.

"Inhabits San Francisco, Calif."—*Uhler.*

Saldula saltatoria Linn 1758.

Linneaus, Syst. Nat. Edn., 10, p. 448, 1758.

"Oval, convex, black, densely clothed with very short yellow hairs. Clavus with a narrow, pointed, subapical, yellow spot; corium; on the anterior margin two long yellow spots, interior to these a row of three spots, the second and third round and white; beyond these a faint, long, yellow ring on the basal half of the disk, followed by a long yellow streak. Legs yellow.

"Head. Clypeus, on its anterior margin, and the face, pale or dusky yellow. Antennæ black, first joint above, and generally the second before the apex, yellow-brown. Eyes black. Ocelli reddish. Rostrum piceous; labrum yellowish.

"Thorax. Pronotum roundly narrowed to the front; sides flattened, but raised within the hinder angles, the margins rounded, narrowly reflexed; posterior margin deeply, somewhat squarely concave across the scutellum, the ends roundly produced over the base of the elytra; disk very finely punctured, the callosity occupying nearly two-thirds of the length, the posterior furrow deep, the single central fovea deep. Scutellum convex, slightly shining; basal half finely punctured, posterior half very finely crenate; the depression large, posteriorly straight. Elytra dull; clavus with a narrow, pointed spot before the apex; corium, sides widely flattened as far as the middle; the margin with a long, narrow, yellow spot in the middle, and a shorter one before, and not reaching to, the

apex; disk outside the first nerve, with three spots in a row, one longish, dull yellow, before the middle, the two others round and whitish, one of them rather beyond the middle, the other opposite the second marginal spot; beyond the first nerve, on the basal half, a long faint ocellus, formed by a narrow, yellowish, oval ring, enclosing a space of the ground color, its basal end being clearer; in a line with this, near the posterior margin, a long yellow streak (sometimes there is a faint, yellowish, interrupted line more towards the inner margin; and sometimes the whole of the yellowish marks on the corium are of larger size, giving a more speckled appearance); membrane yellowish, the suture and nerves black; the first nerve often yellow at its base; between the nerves, beyond the middle, a transverse row of long blackish spots; nearer the base an irregular black spot in the second, third, and fourth cells (sometimes in the second and third only); margin with a long black spot at the end of the first nerve, preceded and followed by a yellow spot; the rest of the margin fuscous-brown, sometimes yellowish internally. Legs pale yellow; thighs with fine, short, yellow hairs on the inner and outer sides, with a row of brown punctures; hinder side of the first and second pairs with a black stripe; apex narrowly black, preceded by a clear space; tibiæ blackish at base and apex, the first and second pairs with a long, subannular, brown spot in the middle; third pair with short, distant, black, spinose hairs; tarsi; first and second joints black, the second, and sometimes the base of the third, yellow; claws brown."

"Abdomen, in the female, the last segment beneath, posteriorly pale ochreous.

"Length, 1½-2 lines.

"Abundant on the margins of ponds and ditches during the summer, and in winter in moss on damp walls, etc."

Reported from New York and Illinois.

Parshley adds Massachusetts, Rhode Island and Connecticut.

Genus MICRACANTHIA Reuter.

"Body small, rather short. Gula short. Eyes very much exserted, strongly converging anteriorly Ocelli slightly distant. Rostrum nearly reaching apex of posterior coxæ. Antennæ rather short, second segment scarcely double the length of the first. Apex of pronotum much narrower than the head with the eyes, sides straight or subsinuate before the apex. Callos by no means reaching lateral margins, extending farther behind middle of the disc, margin of base broadly emarginate. Scutellum longer than wide, base entirely visible, impression far remote from base. Hemelytra entirely or almost entirely (*Humilis* Say) opaque or sericeo-nigra, embolium discolored, entirely distinct from corium; veins of corium entirely obsolete. Apex usually subacuminato-rotundate; first area or anterior base produced before the proximal area by one-quarter or one-fifth part of its own length. Apex most often distinct, sometimes (*Humilis* Say) placed very little above apex of proximal area. Third segment of post-tarsi a little longer than second. Type *Acanthia marginalis* Fall."

Micracanthia humilis Say 1832.

Acanthia humilis Say, Heteropt. New Harmony, 35, No. 4.

"Elliptical, black, velvety, above closely invested with minute yellow prostrate pubescence; the eyes very large, prominent, round, brown, placed obliquely. Head at base, with a narrow neck, conforming to the width of the front of pronotum, black, dull, minutely scabrous; the front very narrow between the eyes, from above blunt, short, a little flattened, with two indented points each side and one in the middle; tylus slightly prominent, and together with the labrum, pale ocherous or yellow, the ends of lower cheeks also ocherous. Rostrum reaching upon the posterior coxæ, pale piceous. Antennæ testaceous, slender, and moderately

long; the apex of the second joint and all of the third and fourth joints blackish; the second joint about twice as long as the basal one and much more slender; the third and fourth slender, subequal; all but the basal one with erect hairs. Pronotum trapezoidal, transverse, very narrow in front, the sides oblique, a little prominent at the shoulders, the lateral margins very slenderly reflexed, decurved, and lost before reaching the anterior margin; the surface very minutely scabrous; anterior lobe moderately elevated, transversely indented on the middle, the impressed line distinct but not very deep; posterior division a little shorter, moderately flattened; posterior margin a very little sinuated, the humeral angles oblique, short, flat, the outer angles subacute, with an oblong tubercle placed next the outside. Scutellum long, moderately depressed in the middle, and more deeply each side, coarsely scabrous at base, finely rugulose on the apical division. Pectus and sternum jet-black, highly polished, closely covered with appressed, fine, white pubescence. Legs pale testaceous; the coxæ black, with white tips; femora broadly banded near the tip with fulvous; tibiæ piceous at tip, and with pale piceous spines; apex of the last tarsal joint black, the nails pale piceous. Hemelytra velvety-black, minutely, densely clothed with black and golden pubescence, minutely punctate; the costal margin broadly arcuated, with the edge narrowly reflexed; the costal area broad, pale yellow or white, with a small, black, longish patch at base, another oblong, large spot behind the middle, against the inner margin, and a trace on the outer margin, and the tip with a transverse black spot; nervures black; middle areole with an oval spot near the outer nervure, basally, a round one a little way behind this, a few specks behind the middle, a dot near the apex inwardly, and a dot near the inner tip of the clavus pale yellow; membrane pale yellow, a little clouded at base and on the apical margin, the apex with a piceous spot on the apex of the outer areole; nervures piceous; the areoles with a transverse series of oblong fuscous spots (sometimes the spots are interrupted, forming a partially double series.) Venter black, clothed with prostrate white pubescence, the posterior margin of the segments slenderly piceous; the apical segment of the female broadly white.

"Length to tip of hemelytra, 3-3½ mm. Width of base of pronotum, 1¼ mm.

"Common in Maryland, within the limits of the metamorphic belt, upon damp sand formed by the disintegration of the rocks, near creeks and brooks, in June and July. It is also common in Northwestern and Northern Florida; and specimens have been sent to me from Texas, Illinois, and Pennsylvania. I have also collected it in Cambridge, Mass., and in the vicinity of Washington, D. C. It occurs likewise in western North Carolina and in Georgia. It is of precisely the same form as *S. cincta* H. Schf., of England and France, agreeing with that species in most of its details, and, upon sufficient comparison, may prove to be the same species."—*Uhler*.

Also reported from Maine, Ontario, Rhode Island, New York, New Jersey, Ohio, Colorado and California.

Parshley adds Massachusetts.

Micracanthia pusilla Van Duzee 1914.

Van Duzee, Trans. San Diego Soc. Nat. Hist., II, p. 32, 1914.

"Size and much the aspect of *humilis* Say, but with broader elytra. Elytra deep black with two white costal spots and the membrane strongly distinguished. Length 3 mm.

"Head as in *humilis*, black, with a transverse white line at the base of the tylus. Antennæ black, the joints subequal; the first a little shorter, the second longer than the third and fourth. Rostrum black. Pronotum broader posteriorly than in *humilis*, sides nearly straight, the humeral angles a little more rounded; hind margin broadly but shallowly excavated. Scutellum as long as broad, with a shallow transverse impression,

and with the pronotum opaque, black and closely minutely sericeous pubescent. Elytra with a somewhat longer pubescence; deep black becoming velvety black toward the apex of the corium and on the tip of the clavus; corium with a square whitish spot resting on the costa and a double one close to the apex; usually there is a small white point on the middle of the corium, one at the inner apical angle and another near the tip of the clavus. Membrane strongly differentiated, whitish hyaline, a little enfumed, the nervures strong, brown; the areoles with a brown subapical mark and sometimes another near the base. Beneath and legs black, the knees, tibiæ except at base and apex and the tarsi, their tips excepted, pallid. In the female the apex of the abdomen and sometimes the slender hind margins of the ventral segments are pale.

"Described from three males and two females taken along the San Diego river at Lakeside, May 7, 1913, and from a moist ravine at Alpine in June. Dr. J. C. Bradley also took this species at Sisson, Cal., in August, 1908. The species can be easily recognized by its small size, intensely black color, the strongly distinguished membrane and the four white marginal spots on the elytra."—*Van Duzee.*

Genus IOSCYTUS Reuter 1912.

"Body oblong. Head subvertical, gula rather brief. Eyes distinctly distant from pronotum, exserted, anteriorly moderately convergent. Part of vertex bearing ocelli slightly elevated. Apex of rostrum reaching intermediate coxæ. Antennæ incrassate, shortly thickly pubescent, sparsely pilose. First segment rather long. Hemelytra laterally little rounded, destitute of white markings. Interior veins of corium obsolete. Embolium entirely distinct from corium. Membrane furnished with four areas. First or internal base produced before the proximal about one-quarter its length. Apex distinctly placed above apex of second. Third segment of posterior tarsi as long as second. Type *Salda polita.*"

Ioscytus politus Uhler 1877.

Uhler, Bul. U. S. G. G. Surv., III, p. 441, 1877.

"Elliptical, highly polished, jet-black, very indistinctly punctate; the whole upper surface set with erect, remote, brown hairs. Head from above short, vertical in front and a little decurving, dull black, densely and irregularly scabrous and rugulose, the raised margin of the clypeus and the tylus ferruginous or pale piceous. Rostrum pale piceous, reaching between the intermediate coxæ; base of vertex a little convex, formed into a distinct neck, contracted on the occiput; eyes very prominent, brown, placed obliquely. Antennæ setulose, moderately long, stout, the two apical joints about as stout as the basal one; basal joint short, blackish-piceous, paler above; second joint much shorter than the two apical ones united, pale piceous or dull yellow; two apical joints dusky black, subfusiform, subequal in length, but much longer than the basal one. Pronotum subtrapezoidal, transverse, short, highly polished; the callosities forming the anterior lobe very convex, not reaching the sides, with a large, indented point in the center; the posterior lobe much shorter, arched, higher than the anterior one, deeply concave, the humeral angles long, broad, and flat, subtruncated, with an oblong tubercle near the outer angle; the impressed line around the callosities very deep-seated, punctate; lateral submargins broadly flattened, rugulose, the edge recurved, decurving anteriorly. Pleural pieces dull black, obsoletely and minutely punctate; the prosternum very short, scarcely covering the base of the coxæ. Coxæ black; femora dull yellow or ferruginous, the under side of the anterior pair piceous; tibiæ dull yellow, their tips, the tarsi, and nails piceous. Scutellum moderately convex, obsoletely scabrous at base; the apical portion a little less prominent than the base, and the depression between them shallow; the surface faintly rugulose. Hemelytra flat, ferruginous, the clavus dusky black, and the costal area jet-black, polished,

the whole surface minutely scabrous; the costal margin moderately arcuated, a little broadly and almost uniformly reflexed; membrane very long, pale dull yellowish, somewhat clouded basally, the nervules piceous, long and almost straight. Venter black, highly polished, minutely punctate and pubescent; the genital segment and sometimes the posterior edges of the others testaceous. The costal margin is testaceous in two specimens, in which the black of that area is much reduced and limited to the posterior portion, inwardly.

"Length to tip of membrane, 4½-5½ mm. Width of base of pronotum, 1½-1¾ mm.

"From San Diego, Cal. Kindly sent to me for examination by Dr. Hagen from Museum of Comparative Zoölogy."—*Uhler.*

Also reported from Arizona.

Ioscytus politus var. *flavicosta* Reuter 1912.

Reuter, Of. Finska Vet. Soc. Forh. III, Afd. A, No. 12, p. 21, 1912.

"Specimens from Utah a half smaller than the type of *polita* from California. The costal area of corium and embolium black, while in the type example the entire corium, with the exception of the outermost point, rust-red and embolium yellow."

Genus LAMPRACANTHIA Reuter 1912.

"Head (brachypterous form) as broad as base of pronotum, subvertical. Eyes strongly exserted, distant from apex of pronotum. Rostrum reaching to base or apex of posterior coxæ. Pronotum shiny, strongly narrowed toward apex, marked by an apical stricture, posteriorly terminated by a punctate impressed line. Sides sinuate, posterior angles prominent. Sulcus terminating callos posteriorly marked with impressed points and longitudinal wrinkles placed far behind the middle. Hemelytra most shiny. Abdomen of brachypterous form a little produced, oval, convex, toward side and apex decurvate, clavus distinct, but corium and membrane coriaceous, merging into one. Veins wanting, or most obsolete. Embolium narrow deplanate. Type *Salda crassicornis.*" —*Uhler.* Reuter thinks *S. anthracina* Uhler "Ohne zweifel zur derselben Gattungen gehort."

Lampracanthia crassicornis Uhler 1877.

Uhler, Bul. U. S. G. G. Surv., III, p. 438, 1877.

"Still more slender than the *S. anthracina*, brassy-black, very highly polished, the upper surface with black erect pubescence.

"Head long, anteriorly oblique, moderately long and narrow, the eyes very obliquely prominent; vertex a little rugulose, the front dull, somewhat shagreened and flattened; the tylus a little prominent, cylindrical, highly polished; the throat concave. Antennæ short, stout, the basal joint short, stout, black, yellow at tip; the second joint yellow, about as long as the third and fourth united, much more slender than either of the others, a very little thicker at tip; third joint much thicker, both third and fourth joints subfusiform, black, more conspicuously hairy, equally thick, much longer than the basal one, the last a little longer than the preceding. Rostrum reaching to the tip of the posterior coxæ, rufopiceous, paler at tip. Pronotum sub-campanulate, long and narrow, with the disk much elevated, very convex, occupying all the surface excepting the very narrow posterior lobe, twice indented in the center, bounded behind and each side by a deep, transverse, coarsely punctate line, the posterior lobe consisting of only a slightly elevated linear tablet on the posterior margin, the margin proper moderately concave, the angles produced, acute; the sides deeply decurved, with the edge narrowly recurved, thinning out anteriorly, and bending down at the anterior end; the anterior margin truncate; the submargin with an impressed, punc-

tate line. Scutellum strongly elevated at base, a little rugulose, deeply depressed on the middle and posteriorly. Legs and coxæ bright yellow, the femora faintly tinged with brown, and the tips of tibiæ and tarsi piceous. Venter black, minutely pubescent, the apex a little tinged with piceous. Corium and membrane coalescing, both coriaceous, long and narrow, convexly arched, deflexed on the sides, the part representing the membrane running off to an oblique rounded tip, with the nervures almost effaced.

"Length to tip of venter, 4½ mm.; to end of hemelytra, 4¾ mm. Width of base of pronotum, 1¼ mm. One specimen from the vicinity of the Saskatchewan river, collected by Robert Kennicott.

"This is surely only the dimorph of the form with perfectly developed membrane. In the *S. anthracina* parallel forms occur, the one with a distinct membrane and the other with the membrane thickened and almost as coriaceous as the corium proper; also, the bounding nervure is faint and almost obliterated, almost the same as in this form of *S. crassicornis.*

"In the present specimen, the nervules of the membrane are very indistinct."—*Uhler.*

Genus SALDOIDA Osborn 1901.

"Head narrower, eyes nearer together than in *Salda*, ocelli approximate, frontal ridge weak, becoming obsolete at base of tylus, bucculæ enlarged; antennæ with the two distal joints incrassate, rostrum as in *Salda*, basal joints very thick, second elongate, terminal very slender. Prothorax bearing two very prominent conical tubercles on anterior lobe, which is narrow, cylindrical, not carinate anteriorly; posterior lobe short, carinate laterally, widening rapidly to humeri."

Saldoida slossoni Osborn 1901.

Osborn, Can. Ent., XXXIII, p. 181, 1901.

"Hind angle of pronotum obtuse, not produced into a sharp angle or horn. Light brown, marked with reddish-yellow and black, face testaceous. Female, length to tip of elytra, 3 mm.; width at humeri, scarcely 1 mm.

"Head obtusely triangular, subcordate, inclined, the part in front of the eyes nearly equal to eyes in length, very sparsely set with erect hairs; eyes large; vertex narrow, less than width of eye; ocelli minute, set close together; antennæ long, joint two longer than one, equal to three, three much swollen, four equalling one in length, and about half as thick as three; rostrum reaching to apex of hind coxæ. Prothorax with two very large, erect, conical tubercles occupying the upper surface of the anterior lobe; posterior lobe short, much widened behind, concavely emarginate, the lateral angles obtusely angulate. Scutellum large, anterior border convex, surface polished, minutely punctate, apex inflated, highly polished. Elytral membrane subhyaline, with four cells and a wide margin, wings reaching to tip of elytra, milky hyaline.

"Color: Vertex black, with margins next eyes red-brown; face and rostrum testaceous, antennæ, basal two-thirds of second joint and all of third fuscous, apex of one and two whitish, fourth yellowish brown, darker at base and minute tip; prothoracic tubercles red-brown, posterior lobe yellowish brown, anterior margin and band back of the tubercles black; scutellum black, apex piceous brown; elytra brown, claval suture and apical margin of corium black, corium with two triangular whitish spots, the bases of which merge into the hyaline costa, membrane with fuscous base and hyaline apex; beneath black, with throat, pleural pieces, coxæ and legs yellowish brown, darker on disc of coxæ, apical portion of femora and base of tibiæ, the apex of tibiæ and last joint of tarsus, fuscous; margin of last ventral segment whitish.

"Described from one specimen (female) from Florida, collected by Mrs. Annie Trumbull Slosson, to whom it is most respectfully dedicated."

Saldoida cornuta Osborn 1901.

Osborn, Can. Ent., XXXIII, p. 181, 1901.

"Hind angles of pronotum produced into conspicuous horns. Black, marked with brown. Female, length 2.5 mm.; width at humeri, 0.75 mm.

"Vertex and front minutely gibbous, sparsely set with short appressed hairs; ocelli minute, approximate; antennæ with joints one, two and four nearly equal in length, joint three about one-half longer, and much swollen, fourth less swollen; rostrum about reaching hind coxæ. Conical tubercles of the pronotum very slightly divergent, otherwise almost precisely like those of *slossoni* in shape; the posterior lobe of pronotum very short, posterior angles produced into prominent upturned horns, with a blunt polished tip. Scutellum minutely roughened, becoming smooth at apex, not inflated. Elytra subhyaline on costa, the membrane rather coriaceous, with veins obsolete, apparently with three cells and rather narrow margin. Wings aborted, unless accidentally broken off in this specimen.

"Colour: Vertex, front, third joint of antennæ, prothorax except posterior horns, scutellum, claval sutures and apex of corium, pectus and base of last ventral segment, black; clypeus, rostrum, joints one, two and four of antennæ, posterior horns of pronotum, coxæ and apices of femora, reddish brown; a brown patch on disc of clavus and base of corium, a whitish oblique spot on corium merging into the hyaline costa. Membrane deeply infuscated; the first and fourth joints of antennæ are widely whitish, as also the hind coxæ, base of femora and the apical two-thirds of last ventral segment, the central part of which is transparent, showing ovipositor clearly.

"Described from one specimen (female) collected by Mrs. Slosson in Florida."

B. Biology of the Saldidæ.

General Habits of the Family. These agile bugs for the most part inhabit damp soils about pools, along the margins of ponds and upon the shores of fresh and salt waters. Kirkaldy says that one species is found "far away from moisture on sandy commons or moors, under heather or in sand pits." They are very lively creatures and difficult to capture. When disturbed they leap from the ground, arise a few feet into the air by the aid of their wings, and alight a short distance away. Uhler has made a special study of these insects and tells us that when they alight "they take care to slip quickly into the shade of some projecting tuft of grass or clod where the soil agrees with the color of their bodies." Some species dig holes for themselves, and live for a part of the time beneath the ground, according to Uhler. This writer also compares the quick short flights of the Saldids with those of the tiger beetles and notes that *Salda signoretii* (now *Pentacora signoretii*) may be observed running swiftly about over the damp surface of the sandy beaches of Maryland in company with *Cicindela dorsalis*, searching for food and thrusting its rostrum into drowned flies and other insects. Latreille, 1803, stated that they probably fed upon aquatic insects, especially Diptera.

Direct observations upon their feeding habits in nature are scant. The writer has kept them in the laboratory upon a diet of dead flies, etc. From their behavior, however, he believes they capture living insects upon occasion.

Their resemblance to their surroundings and their rapid, erratic movements have enabled them to get on well in the world. As evidence of

this we have a relatively large number of species and often abundant numbers in a favorable situation. Uhler states that:

"America is the principal dwelling place of these remarkable insects, and in North America especially may be found the greatest variety of species, and the most attractive designs of ornamentation. Every considerable sea-beach from Cape Cod to the Florida reefs presents some local form or variety of this type, and on the marshy spots of the sea islands, droves of them may be frightened up as the explorer passes from one bare spot to another. One large black species is found as far north as the Great Bear Lake, and near the Yukon river in Alaska. Some of the smaller species, with black ground color, marked with white, are distributed over the greater part of North America, being found near streams of water or about the drier parts of fresh-water marshes. A group of pale horn-colored species with hairy surfaces, inhabit the marshes of Eastern New England and of Illinois. The shores of the Great Lakes are tenanted by other forms, which are often caught by driving storms and piled upon the low beaches at the edge of the tide."

The writer has found them in numbers about pools, usually with one species in predominance.

No one has recorded the rearing of any species from egg to egg, and for that reason the writer is attempting to carry two Kansas species through their development.

NOTES ON SALDA ANTHRACINA UHLER AND LAMPRACANTHIA CRASSICORNIS UHLER.

On the borders of the Meadow Pool at Ringwood Hollow, N. Y., two species of Saldids were found in number along with a species of Hebrus, elsewhere noted. The Saldids were in the sphagnum-like moss and about the sedge and rush clumps. Both species are shiny black somewhat hirsute species with tegmina coriaceous. The former is plump bodied and of fair size, the latter a smaller more slender form. They have the same habitat and attempt to escape by running and by quick short jumps rather than by flight. Their food habits, mating and oviposition habits are about the same.

When first observed about the Ringwood pool on June 22, only adults were found of the *L. crassicornis* while the *S. anthracina* were all in the nymphal stage. June 28 many of the latter were in the last nymphal instar. Eleven of these nymphs were brought in alive placed in a large slender dish and fed flies, Jassids, etc. July 1 one became adult and by July 5 there were four adults, the remainder following shortly. Mating took place and eggs were found between the leaflets of the moss on July 16.

It was noted above that the smaller species was in the adult stage when first taken. These were at once placed under observation in jelly glasses containing a quarter inch of moist sand. One pair was placed in each jelly glass in order to get a record of mating and egg laying. Most of the observations relate to this species, although they apply almost equally well to the larger form.

Habits. They are shy, cautious creatures which hide among the clumps of shore grass and moist patches. They feed upon such insects as they may chance to meet, even the disabled of their own kind.

Mating. The male follows the female about for some moments before mounting her with a sudden pounce. He appears to keep at a respectful

distance and if his clasp is not secure, he gets away quickly. And well he may, for in some of the glasses the males were killed and in one case the female was observed still feasting upon the carcass of her unlucky mate. The males are smaller and more slender than the females and in mating take a position on the left side of the female and a trifle below, appearing to grasp the femur of the female's middle left leg. The middle and right hind legs of the male lie along the left margin of the female. With antennæ directed backward he remains rigidly in place while the female moves about with antennæ directed forward. It was not possible to ascertain how the male could retain his position so rigidly in place. All efforts to be certain that his legs were involved in clasping failed. Mating took place at short intervals and often lasted for half hour periods. One pair was observed to mate repeatedly every day from June 28 to July 16, when the male was found dead. Eleven eggs had been laid during this time.

Oviposition. The eggs are hidden away, one in a place as a rule, between the leaflets of moss or beneath the sheaths of the shore grasses. When in the moss they are exceedingly inconspicuous and when at the base of grass clumps remain concealed until disturbed. Illustrations are submitted herewith to indicate the manner in which they are to be found and a sketch of the ovipositor of the female to show the instrument by means of which the eggs are hidden. See plate X, figure 12, and plate VI, figure 7.

Eggs of *Salda anthracina* Uhler.

Size. Length, 1.05 mm.; diameter, 0.375 mm.

Shape. Elongate-cylindrical, one end broadly rounded, the other constricted near the end and curved upward in such a manner that in profile one side appears slightly concave and the other considerably convex.

Color. Pearly white and shiny, smaller and slightly whiter. Surface finely granular as seen under low power compound.

Nymph of *Salda anthracina*.

When the species was first taken all the specimens were in the last and next to the last instar. The nymphs are somewhat more flattened than the adults. The antennal segments are thicker in proportion to their length and the eyes much less protuberant. Ocelli are lacking in the nymph while the adult possesses a pair of prominent ones. The tarsi are two-segmented in the nymph, three in the adult. Secondary sexual characters not apparent in the nymph.

Egg of *Lampracanthia crassicornis* Uhler.

Size. Length, 1 mm.; diameter, 0.3 mm.

Shape. Elongate-cylindrical, both ends bluntly pointed, one more than the other, and curved upward. Camera lucida drawings of the eggs of both species are shown on the plate X, figures 6 and 7.

Summary. The species of Saldids observed will live upon recently killed insects. They place their eggs beneath the leaf sheaths of moss and about the base of grass clumps. These species are inhabitants of the

sphagnum, moss and shore grasses. They were numerous about a swampy pasture pool in New York.

Reuter, who created the genus *Lampracanthia* for Uhler's *crassicornis* species, stated that though he had never seen *S. anthracina* Uhler it probably should be placed with *Lampracanthia crassicornis.* The habits, the similarity of their eggs and their method of deposition is certainly in favor of such a consideration. Yet when one examines Uhler's *coriacea,* one is justified in believing *anthracina* more nearly related to it than to *L. crassicornis.*

Family HEBRIDÆ A. & S. 1843.

(Hebrus from Hebre, a river in Thrace A. & S.)

A. TAXONOMY OF THE HEBRIDÆ.

Family Characteristics. Very small plump bodied insects. The adults in the genus *Hebrus* always winged while those of *Merragata* are dimorphic. Antennæ five-segmented in *Hebrus,* four in *Merragata.* Ocelli present; head and thorax sulcate beneath; rostrum three-segmented; tarsi two-segmented. Until recently but one genus was recorded for the United States. In February, 1917, Carl Drake added the genus *Merragata* to our fauna with two new species from Ohio. We have thus recorded six Hebrids for the United States, four in the genus *Hebrus* and two in the genus *Merragata.*

Historical Review. These insects were placed with the group which now forms the Gerridæ (Amphibicorisæ Duf. and Hydrodromica Fieb.) in its broad sense by Brulle 1835, Burmeister 1835, Blanchard 1840, Westwood 1840, Fieber 1851-1861, Barensprung 1860, Walker 1873, J. Sahlberg 1875, Saunders 1875 and Kirkaldy 1909. In 1884 Berg placed them beside the above forms. They were treated as relatives to the Tingidids by Amyot and Serville 1843, Flor 1860, Douglas and Scott 1865, Puton 1875-1899, and by Saunders 1892. Lethierry and Severin 1896, Distant 1904, Champion 1898 and Oshanin 1908 placed them between the Aradids and Gerrids (Hydrometridæ). Herrich-Schaffer classed them with the Lygæids. Handlirsch 1908 appears to derive them from the Hydrometrid group and places them next to the Lygæids according to his diagram, although Reuter says this author is uncertain in regard to them. According to Reuter's table 1910 they arise doubtfully from the Neidoideæ group. The Tingididæ are their nearest relatives within this group. The Coreidæ lie just beyond in the next group. In 1912, Reuter removes them to another series altogether and lists the Hebrids under the superfamily Reduvioidiæ because of their similarity to certain Nabids. Horvath, Bergroth and Champion consider the Hebrids and Mesoveliids closely related, as does Van Duzee.

KEY TO GENERA.

A. Antennæ consisting of four segments, the minute segment at the base of the third segment being counted as a part of the third segment. *Merragata* White.

AA. Antennæ consisting of five segments, the minute segment at the base of the third being counted as a part of the third segment. *Hebrus* Laporte.

Genus MERRAGATA White 1877.

Description of Genus. Much like Hebrus but differs from it in having the fourth and fifth segments of the antennæ conjoined without a trace of a suture between them. Tarsi two-segmented. The antennæ are four-segmented, the minute segment at the base of the third segment of the antenna not being counted as a true segment, but as part of the third. Heads of the Mexican and Central American species have either a fine or a distinct median longitudinal groove, while the Nearctic forms have the head with two longitudinal grooves, converging anteriorly, and a median ridge between these grooves. Dimorphism seems to be characteristic of the genus, macropterous and brachypterous forms occurring in the same species, the latter form having only short wing pads that vary somewhat in size in the same species and in the different species.

KEY TO SPECIES OF MERRAGATA.

(From Drake.)

A. Apex of scutellum bifid, antennal segments two to four subequal, the basal segment shortest and stoutest. *M. lacunifera* Berg.

AA. Apex of scutellum not bifid.

- B. Head with either a faint or a distinct median longitudinal groove.
  - C. Antennæ short, less than twice the length of the head; segments from one to three subequal, the fourth rather stout and fusiform. *M. hebroides* White.
  - CC. Antennæ longer; third segment slender and very much longer than the second; fourth segment slender and subfusiform.
    - D. Pronotum moderately constricted at the sides. *M. brevis* Champ.
    - DD. Pronotum deeply constricted at the sides. *M. leucostricta* Champ.
- BB. Head with two longitudinal grooves converging anteriorly and with a median ridge between these grooves.
  - C. Pronotum moderately constricted at the sides, the disc with a broad, deep, longitudinal furrow; color blackish, the hemelytra white with distinct dusky patches. *M. foveata* Drake.
  - CC. Pronotum more abruptly constricted, the disc with a shallower groove; color reddish-brown or dark reddish-brown, the dusky patches of the hemelytra evanescent. *M. brunnea* Drake.

Of these six species only two are recorded for the United States. These were described by Drake and are given herewith:

Merragata foveata Drake 1917.

Merragata foveata Drake, the Ohio Journ. Sci., vol. 17, pp. 103-104.

"Very like *M. hebroides* Champion in size, color and antennal characters, but readily separated from it and the other Mexican and Central American species by having the head bisulcate longitudinally and with a distinct median ridge between these furrows. From its only Nearctic congener, *M. brunnea* Drake, it is easily recognizable by the less abruptly

constricted sides of the pronotum, the larger size, the angular nervure on the inner margin of the corium, and blackish color.

"Moderately large and robust. Head long, hairy, strongly deflected, with two distinct, longitudinal furrows (the furrows converging anteriorly) and a distinct median ridge between these furrows, the sides very strongly depressed above the eyes, and a longitudinal furrow just beneath the eyes and antennæ. Eyes prominent, the facets few and large. Antenniferous tubercles large, prominent. Antennæ very short, a little longer than the head; first, second and third segments subequal, the fourth stoutest, longest and fusiform. Bucculæ large, with a longitudinal furrow on each side at the base. Pronotum rugulose, very coarsely punctate or pitted, beset with a few hairs, moderately constricted at the sides, with a broad, median longitudinal furrow in which are two rather regular rows of foveæ, with a rather broad, transverse, punctate depression on each side just back of the collar. Collar prominent, ornated with foveæ. Humeri well defined by a sulcus in which is a row of six or seven foveæ; posterior margin of pronotum also with a transverse row of foveæ. Sides of thorax with quite regular rows of foveæ. Scutellum distinctly carinate. Rostral sulcus broad; rostrum extending a little beyond the thorax. Acetabuli very far apart, especially the intermediate and posterior pairs. Legs rather stout, hairy; claws very long, almost half the length of the terminal tarsal segment. Entire body velutinous. Abdomen densely hairy beneath; connexivum narrow. Venter longitudinally depressed in the male, concave in the female. Hemelytra with large, hairy nervures. Length, 1.6 mm.; width, .75 mm.

"Color: General color blackish. Antennæ dark-yellow, the terminal segment infuscated. Prothorax blackish, the disc more or less reddish-brown. Legs testaceous, the tips of tarsi infuscated (the claws excepted). Body beneath blackish, the thorax and abdomen covered with a grayish pubescence. Hemelytra white, with dusky patches; nervures brownish-black. Wings white, opaque."

Numerous macropterous examples, taken in a stagnant pond at Ira (Summit Co.), Ohio, August 31, 1916, by Professor Hine and the writer. I have received a specimen from Prof. C. P. Gillette labeled Fort Collins, Colo., August 8, 1898.

Merragata brunnea Drake 1917.

Merragata brunnea Drake. The Ohio Journ. Sci., vol. 17, p. 105.

"Shorter than *M. foveata* Drake, the pronotum more abruptly constricted on the sides, the inner margin of the corium rounded, the head and the pronotum reddish-brown or dark reddish-brown, and the dusky patches on the hemelytra evanescent.

"Macropterous form. Head hairy, strongly deflected, the sides strongly depressed above the eyes, with two longitudinal furrows converging anteriorly (a median narrow ridge between the longitudinal furrows), a longitudinal furrow on each side of the head just beneath the eyes and antennæ. Antenniferous tubercles large and prominent. Antennæ short, a little longer than the head; first, second, and third segments subequal; fourth segment longest, stoutest, fusiform. Rostrum reaching a little beyond the posterior coxæ. Pronotum rugulose, coarsely punctate, sparsely hairy, the sides more abruptly constricted than in *foveata*, with a transverse, punctate depression on each side just back of the collar. Collar prominent, ornated with foveæ. Scutellum with a narrow median carina. Sides of thorax with somewhat regular, transverse rows of foveæ. Abdomen hairy beneath; venter is slightly depressed longitudinally and convex in the female. Hemelytra with large, prominent nervures; the inner nervure of corium broadly rounded. Wings about as long as the hemelytra. Length (♂ and ♀), 1.45 to 1.5 mm.; width, about .65 mm.

"Color: General color reddish-brown or dark reddish-brown. Antennæ testaceous, the apical segment infuscated. Legs testaceous, the apical segment infuscated (claws excepted.) Abdomen beneath blackish, border with reddish-brown: Hemelytra white, the dusky patches evanescent.

"Brachypterous form. Head and antennal characters agree with the macropterous form. Prothorax less constricted on the sides, the humeri less prominent, the disc with a shallower median, longitudinal groove. Scutellum broader. Connexivum very broad. Wing pads vary in size, but usually very small.

"Color: General color, reddish-brown. Wing pads white. Legs and antennæ agree with long winged form."

"Numerous examples, taken at various times during the summer at Hebron (Licking Co.), Sugar Grove and Rockbridge (Hocking Co.), Delaware (Delaware Co.), Columbus (Franklin Co.), and Ira (Summit Co., one specimen only.)"—*Drake.*

Genus HEBRUS Curtis 1833.

Description of Genus. Head pointed and elongated in front. Eyes small, globose, not prominent. Ocelli very distinct, placed on the posterior line of the eyes and near them. Antennæ five-segmented with short articulations between the second, third and fourth. Rostrum four-segmented, the first two very short, third and fourth long, tip reaching to the third pair of coxæ. Rostral chamber wide, sides raised posteriorly, end in a point projecting a little over the prosternum.

Pronotum deflected, hexagonal, broader than long; anterior margin incrassated; sides widely divergent to the rounded and prominent hinder angles, but deeply constricted before the middle; hinder sides rounded; posterior margin straight; disk in the middle with a short, broad, longitudinal channel, of which the sides are somewhat bluntly raised, on each side of it anteriorly, a deep fovea, whence a depression extends to the anterior angles; hinder portion flat, convex, higher than the anterior part. Scutellum short, broad, reversed trapeziform, posteriorly raised, concave, with a central longitudinal keel. Elytra very broad posteriorly; corium on its anterior margin not half the length of the elytron, on the inner margin shorter; posterior margin straight, oblique; the breadth is about half that of elytron, anterior and inner margins with an incrassated nerve; the region of the clavus wide, membranous, posteriorly not perceptibly separated from the membrane; membrane very broad, thin, without perceptible nerves. Wings with one triangular, basal cell, and one nerve at its end. Sternum flat, with a wide rostral channel. Legs stout, posterior femora curved, on each segment of sternum very wide apart, widest on the third; tarsi three-segmented; first very small; second longer, stout, the end oblique, clasping the third which is long, stout, thickest at the end, rugulose and hairy, with two very short curved claws; the second and third segments are so closely united as to appear to form but one long ovate segment.

Abdomen convex beneath but flattened in middle, apex rounded, connexivum narrow. Genital segments not visible from above, beneath projecting through a circular opening in the last abdominal segment; in the two, the first short, annular, the second at base cylindrical, but then rapidly narrowed to a point, which is curved upwards. In the three, the

first small, the second and third cleft longitudinally in the middle, but not parted. (D. & S. and A. & S.)

There are four species listed for the United States, of which three are eastern and southern, and one western.

KEY TO SPECIES OF HEBRUS.

A. Membrane of hemelytra with three or four light spots.
 B. With four conspicuous whitish spots on membrane. Elytra with a long wedge-shaped mark on clavus, and a white streak on corium. *H. consolidus* Uhler.
 BB. With three white spots on membrane. *H. burmeisteri* L. & S.

AA. Membrane of hemelytra without distinct light spots.
 B. Membrane pale, dull brown, slenderly margined with paler brown. Pale streak on corium. Head stout, vertex and face very convex. *H. sobrinus.*
 BB. Membrane pale brown, with a pale spot each side next the cuneus; head nearly as long as prothorax. *H. concinnus.*

Hebrus consolidus Uhler 1894.

Uhler, Proc. Zoöl. Soc., London, p. 222, 1894.

"A little more compact than *H. sobrinus* Uhler, with the transverse suture separating the lobes not so deep, color fuscous, the surface above finely pubescent, more or less spread with whitish bloom. The head moderately produced before the eyes, somewhat tinged with rufous, a little rough between the eyes; the throat pale rufo-testaceous; antennæ dull rufo-testaceous, usually darker at the points of articulation, the first and second joints paler, subequal in length, thickened and black at tip; rostrum yellowish testaceous reaching the posterior coxæ; the bucculæ, coxæ, trochanters and legs pale testaceous, with the knees and tarsi sometimes infuscated. Pronotum broad, moderately sinuated before the posterior lobe, with the lateral margins reflexed, and the humeri prominent and blunt; the collum exceedingly narrow and almost obsolete; the posterior margin deflexed, broadly rounded. The base of the scutellum lunately tabulated, with the posterior portion triangular and depressed. Hemelytra chestnut-brown, minutely pubescent, the corium marked at base with a white wedge-shaped spot, basal half of the costal border dull yellowish; the membrane long, dusky, marked at base with a short curved streak, also each side with a bent spot, and on the middle toward the tip with an oblong spot, all of which are obscure whitish. Venter rufo-piceous, margined with yellow.

"Length to tip of abdomen, 1¾ mm.; width of pronotum, ¾ mm.

"Several specimens were collected on the Mount Gay estate August 26, at the roots of grass on muddy soil adjacent to pools of water, and September 6 at an altitude of 30 feet, on grass and weeds growing out of a pool of water; also on the Telescope estate, and at Helthazer, March 5, on the open sandy shore of a stream, under decaying leaves."

Locality: Florida.

Hebrus burmeisteri L. & S. 1896.

Leth. & Serv., Cat. Gen'l Hemip., III, p. 51, 1896.

In Burmeister's text, following a description of *Hebrus pusillus* in Latin, this author describes in German some specimens from Pennsylvania. Lethierry and Severin raise these to the dignity of new species, which they name in honor of Burmeister. The descriptions follow:

"*Hebrus pusillus* Fuscus. Base of antennæ and legs fulvous, basal region of elytra obliquely elongate and membrane with three white spots. Length, ¾ line.

"In specimens from Pennsylvania, the entire body, especially the head, is reddish-brown, the scutellum somewhat prominent, the sides of abdomen parallel, thence behind as broad as in front, then rounded off. The ocelli very distinct."

Locality: New Hampshire, Massachusetts, New York, Pennsylvania, Illinois.

Hebrus sobrinus Uhler 1877.

Uhler, Bul. U. S. G. G. Seurv., III, p. 452, 1877.

"Robust, brunneo-fuscous, beneath mostly blackish-piceous, with the sternum, coxæ, and legs testaceous. Head stout, not so long nor as tapering as in *H pusillus* Fallen; the vertex and face very convex, at the tip thickly hairy. Antennæ dull testaceous, pubescent; the basal joint thickest, narrowed at base, longer than the second; the third longest, slender, of the same thickness as the succeeding ones. Under side of the head and bucculæ dull testaceous; the rostrum slender, reaching upon the venter, dull testaceous. Eyes dark brown, with few and coarse facets. Pronotum broader than long, flattened; the humeri well defined by a brown sulcus; impressed line between the lobes distinct, as also the three indentations upon the center, those each side less distinct; the surface very minutely punctate. Pleuræ darker, having a few, very remote, coarse punctures. Venter smooth, black-piceous, densely sericeous pubescent, margined with dull fulvous. Hemelytra pale brownish, minutely pubescent; the nervures thick, darker; the costal margin almost straight, a little incurved near the tip; membrane scarcely reaching the tip of the venter, pale, dull brown, slenderly margined with paler brown. Tergum fuscous, whitish, sericeous pubescent, the reflexed margins yellow. Length, scant 2 mm. Width of base of pronotum, ¾ mm.

"A few specimens occurred on margins of ponds west of Denver."

Localities: Colorado, Arizona, California.

Hebrus concinnus Uhler 1894.

Uhler, Proc. Zoöl. Soc., London, p. 221, 1894.

"Form of *H. pusillus* Fallen. Fuscous or rust-brown above, minutely pubescent, with the disk of pronotum moderately flat and the collum well defined and fulvous. Head nearly as long as pronotum, dark brown, minutely scabrous, tinged with rufous at tip; antennæ dusky testaceous, sometimes fuscous on the tips of the two basal joints, the first of these a little longer than the second, generally paler at the base, the three following ones very slender, set with erect pubescence, the third longer than either of the following ones, the fourth and fifth subequal; underside of head and the bucculæ testaceous; the rostrum pale testaceous, reaching to the posterior coxæ. Pronotum with a depressed, curved, rufous margin extending a little over the base of the scutellum; the lateral margins notched behind the swollen anterior lobe; the humeral angles prominent, rounded, with a callous long submargin; the middle line impressed, and each side of it with a few coarse punctures anteriorly and with a group of less coarse ones posteriorly; the reflexed lateral margin and underside of collum rufous. Scutellum dull fuscous, rough and uneven; legs testaceous, a little dusky on the knees, tibiæ and tarsi. Hemelytra scarcely longer than the abdomen, obscurely sericeous pubescent, pale smoke-brown at base, fuscous at tip, with a stripe of white running out from the base of the clavus, and a longer pale streak on the subcostal long areole; the membrane pale fuscous, with a pale spot each side next the cuneus; the margin of the entire wing coverts, including the membrane, also pale next the tip; there is in some specimens a faint trace of another spot. Venter polished, fuscous

black, minutely sericeous pubescent, with a slender black stripe along the middle. Length to tip of venter, 2¼-2½ mm.; width of pronotum, 1 mm.

"Three specimens of this insect were captured on the Mount Gay estate and Balthazar in June and August. During the latter month they occurred at the roots of grass, on muddy ground near pools of water. This species is a common one which has been met with in the Atlantic states and the West Indies, and it also occurs in California and Washington states. In Maryland it lives on the damp sand or mud of small pools beside streams of water, in spring and late summer. The unwinged individuals may be found skimming over the surface of quiet water from spring until the end of summer."

Localities: Quebec, Ontario, New York, New Jersey, Pennsylvania, Maryland, Florida, Illinois, Colorado, California and Washington.

B. Biology of Hebridæ.

General Notes These small, plump-bodied insects live about the margins of pools and upon the floating vegetation. They are predatory in habits.

Genus MERRAGATA White.

Little or nothing is known of their life history.

Carl Drake says that those he has studied "are dwellers in still and stagnant waters. Their favorite haunts are secluded coves of lakes, ponds, and swampy pools, where the water is shallow, and where there is an abundant growth of aquatic plants. I have rarely seen them on the damp ground near the water's edge. The Merragatas are aquatic pedestrians, capable of standing, walking, and running upon the surface of the water, their entire body being covered with a velvety pile which effectively sheds the water and prevents them from becoming wet. They can move forward or backward, but the usual mode of progression is a steady forward movement, all three pairs of legs being used in locomotion. I have often found them on Lemna, Nymphæa, and various other aquatic plants. It is not uncommon to find them on the underside of floating leaves, or even among the roots of floating water plants. When submerged in the water, the insects are surrounded by a film of air which enables them to stay beneath the surface film for a considerable period of time. In an aquarium I have often watched them standing or walking for a period of a half hour or a little longer on pieces of cork or plants that were beneath the water. Occasionally, they will walk down the sides of the glass aquarium beneath the surface of the water, and when the water is shallow, they will walk across the bottom and come up on the opposite side."

Genus HEBRUS Curtis.

These insects are to be found in the midst of moss clumps and shore grasses by the water's edge and upon the moist earth thereabouts. They are best observed by disturbing moss and grasses, from which they then come forth. They run about upon the mud or even upon the water, though they do not take to the water as readily as do the Merragatas and Microvelias. A few notes on the habits of these insects are given in "Brauer, 1909"; in "Guide to British Water Bugs," by Kirkaldy, 1899; in collecting notes by Bueno, and in Kulgatz's article "Die Aquatilen Rhynchoten Westpreuss," 1911.

Kulgatz says that *Hebrus ruficeps* lives in Sphagnum and has been taken in January, May, June, July, August and September, October and November. He found them under a 16-cm. snow layer, wintering as

adults, in November and also thawed adult females from ice in January. He has taken nymphs and adults in July and August, and notes that the nymphs lack ocelli.

Kirkaldy found this among Lemna and Sphagnum. Bueno reports having taken *H. concinnus* on the damp edges of a cranberry bog on Long Island and at White Plains on the muddy bottom of a dried up temporary pool.

Hebrus cincinnus Uhler.

Habitat. This little species was found among the moss tufts and grass clumps and upon the moist earth of the shores of an upland meadow pool at Ringwood Hollow, near Ithaca, N. Y. It was also taken about the waters of the cove just east of the field station. It is an inconspicuous shore bug that frequents the moss and will be taken only when, disturbed in its haunts, it takes to the open areas, even venturing upon the water for a short run. These insects are not as safe upon such a footing as are the little Microvelias which they superficially resemble. Their bodies are sufficiently covered with a fine pile so that, if perchance they do capsize, they have a fair chance of escape. On one occasion a specimen in the laboratory became submerged accidentally. It walked upside down under the surface film as upon a ceiling, stopping now and then to clean the antennæ and limbs as it frequently does when in its normal environment. The body was surrounded by a layer of air which held it up to the surface film. It finally escaped by crawling upon a bit of moss projecting from the water.

Mating. The first adult Hebrid was taken by Mr. C. H. Kennedy on June 4, at Ringwood Hollow. On June 22 the bugs were mating in numbers. The male mounts the female and remains in copula for varying periods of time.

Oviposition. Bugs brought to the laboratory on June 22 were confined in large petrie dishes. These petries were prepared for them by placing some moist sand in the bottom and adding a few sprigs of moss. One June 26 the moss was examined superficially under the binocular and no eggs discovered. A more careful examination with dissecting needles revealed some of the yellowish white eggs, already showing the red eye spots, hidden between the closely approximated leaves. Some of them seemed to lie on the upper concave side beneath the pale green sheath of the moss leaf, as shown in the figure (pl. X, fig. 4). For the most part they were concealed as shown in figure 2 between the leaf and the stem.

In an endeavor to determine whether the female would ever place the eggs in the tissues of plant stems, some females were confined in a small stender dish with a leaf of Moneywort, a soft stem of dead sedge, and a variety of moss having the leaves widely separated and directed outward, thus providing no hiding place for the eggs. Eggs were laid in the mat or tangle of rootlets at the base of the moss, and, in one instance, the tip of one leaf was glued to the one above it and here three eggs were found, as shown in the sketch (pl. X, fig. 4).

Incubation. Eggs laid perhaps June 22 showed red eye spots by the

26th, and hatched two days later, which would give about a week for incubation. More data is really to be desired on this point.

Hatching. In watching the hatching process of this little bug it was seen that upon issuing from the egg, it casts a thin transparent membrane, which surrounds each appendage separately and is of the nature of a true molt. This has been designated elsewhere in this paper as a postnatal molt.

Number of Instars. Not determined for this species, due to the fact that the writer found it necessary to drop the rearing in its midst. Thus data upon maturity, fecundity, etc., are to be desired.

Longevity. Bugs were kept under observation for some two months and the females were laying for the latter half of that time. Doubtless the bugs would have lived much longer.

Food Habits. In the laboratory the bugs fed upon plant lice, midges, mosquitoes, etc., dropped upon the moist earth for them. They would gather about a carcass in numbers. What their source of staple food supply may be in nature was not determined on account of the difficulties involved and the lack of sufficient time.

Behavior. Like the Microvelias, they endeavor to keep their body clean, and perform a toilet quite as elaborate as Bueno has described for *Microvelia americana.*

DESCRIPTION OF STAGES.

The Egg.

Size. 0.625 mm. by 0.325 mm. This represents the size shortly before hatching. Somewhat more slender when deposited. The eggs are large for the size of the bug. One female measuring 0.925 mm. across the prothorax contained four well-developed ova, each measuring 0.625 mm. by 0.25 mm. Figures of female abdomen and of the egg are drawn to same scale. (Pl. X, figs. 2 and 3.)

Shape. Elongate oval; ends rounded; length about twice the width.

Color. Pearly white, changing to yellowish white as embryo develops within. Some appear to be surrounded by transparent gelatine. Under the low-power compound the surface of the egg is seen to be covered by short, irregularly arranged elevations.

In the case of those containing well-developed embryos the eyes show as pink spots and a pair of black dots lie on the ventral side near the apex of the head.

Description of First Instar Nymph.

Size. Length, 0.608 mm.; width, 0.352 mm.

Color. Eyes dark red, body dark in color.

Structural peculiarities. Body plump, head relatively large, prolonged before the eyes so that the head is about two-fifths the length of the entire body. Body sparsely clothed with rather stiff hairs. Limbs similarly clothed, the pubescence being shorter, especially on tarsal segments. Antennæ four-segmented. Segments one and two short and stout, first slightly longer than second. Third segment a trifle more slender and a little longer than first. The fourth is about as long as the other

three together, the outer third tapering asymmetrically to tip. Limbs are stout, and tarsi one-segmented, ending in two apical claws. A single dorsal pore on the anterior margin in the median line of the fourth abdominal segment.

Morphological studies. Aside from the external structures studied by taxonomists, no morphological work has come to the attention of the writer.

Family HYDROMETRIDÆ Billb. 1820.

Limnobatidæ Fieb. 1851.

A. Taxonomy of Hydrometridæ.

Family Characteristics. Exceedingly slender bugs of a dark color that dwell upon the shores and floating vegetation of the water. The adults are dimorphic in respect to wings. The apterous forms are perhaps more common than the winged, especially in the north. The head is as long as the entire thorax, though it too is elongate. Ocelli absent; eyes distant from the anterior margin of the thorax; antennæ four segmented, filiform; rostrum three segmented; tarsi three segmented. One genus and two species in America. At least a dozen species in the world.

Historical Review. Since the genus Hydrometra was established in 1801, these strange bugs have been known best, in this country at least, by the name of Limnobates, which translated into English means marsh-treaders. This name was assigned to them by Burmeister in 1835. Most of the European notes deal with the species *H. stagnorum.* Long before this time, however, we can identify these insects in the literature. Swammerdam 1737 (Hill's Trans. 1758), in speaking of "water Tipula," which he says are worthy of the greatest attention, on account of the wonderful lightness wherewith they run on the surface of the water," mentions a species of this insect, which is "of a wonderful delicacy and of a very singular structure and very slow paced." This, I take it, is Hydrometra. De Geer, 1752, figures a Hydrometrid under the name of *Cimex acus,* while Geoffrey calls it "La Punaise aiguille." It is indeed slender like a needle. Linnæus placed the then known form *stagnorum,* which he described, in the genus *Cimex.* Lamarck is credited by Van Duzee with the generic name of Hydrometra, 1801.

Genus HYDROMETRA, Lam.

Sufficiently characterized by the family description for the present. Two species are listed for this country. They may be separated by the following characters taken from the writings of Kirkaldy and Bueno.

KEY TO HYDROMETRA.

A. Terminal segment of male (from above abruptly enlarged at tip and bearing a well-marked spiniferous tubercle. Caudal margin of this genital segment sinuate in lateral views. *H. martini* Kirk.

AA. Terminal segment of male (from above) swollen in outer half but not abruptly so. Spiniferous tubercle lacking or not prominent. *H. australis* Say.

Hydrometra martini Kirk. 1900.

Kirkaldy, Ento., XXVIII, p. 175, 1900. (New name for *lineata* Say.)

"Fuscous, hemelytra dull whitish with black nervures. Inhabits U. S. Body fuscous or brown, more or less deep; hemelytra dull whitish or dusky, with black nervures; tergum pale, quadrilineate with black; two of the lines on the edge and interval between the two inner lines, dull whitish or bright yellow; the incisures of the segments more or less black; beneath and feet obscure yellowish; thorax with a more or less obvious pale line; length seven-twentieths of an inch. This is very much like the *stagnorum* F., but the hemelytra are not testaceous and there is no thoracic impressed line (male). Body blue-black; thorax with a pale line; antennæ and feet dark honey yellow; tergum and venter without lines."—*Say.*

Distribution: Ontario, Maine, New York, New Jersey, Pennsylvania, Maryland, District of Columbia, North Carolina, Florida, Indiana, Illinois, Louisiana, Texas, Arizona, and Kansas.

Martin, 1900, pointed out genital differences between *H. lineata* (*H. martini* Kirk), which he reared, and the European *H. stagnorum.* The terminal segment of the male of *H. martini* as seen from above is abruptly swollen toward the tip, which is truncate. It bears a prominent spiniferous tubercle which arises shortly before the tip. The lateral caudal margin of this segment is sinuate.

Hydrometra australis Say. 1832.

Say, Heter. N. Harm, p. 35, 1832.

"Head beyond the eyes, a little longer and a little more dilated at tip than *H. martini* Kirk. Second joint of the antennæ a little more dilated at tip. Abdomen with five lateral whitish points. Inhabits New Orleans;" after Say. Bueno, 1905, points out that the genital characters raise Say's variety to a species rank, the male terminal segment as seen from above being swollen, but not abruptly so and bearing a small tubercle if any, while the lateral margin is straight, not sinuate as in *H. martini* Kirk. On plate XIII are figures of the male genitalia of both species, taken from Bueno.

Found in Georgia, Florida, and Louisiana.

B. Biology of Hydrometra.

General notes. A few early notes on the behavior of this bug have been mentioned. These dealt with their habitat and feeding habits. In 1895 Arrows, in *Science Gossip,* gave an account of the habits of *Hydrometra stagnorum.* This was followed in 1899 by two papers, one on the mating, by Palumba, and the other by Kirkaldy in his "Guide to the Study of British Water Bugs." As for our own American species we have Martini's interesting paper, which appeared in *Canadian Entomologist* for March, 1900, and Bueno's notes in 1905 (Can. Ent.). O. Heidemann, in the Journal N. Y. Ent. Soc. for the same year, mentions the number of generations and developmental period.

Biology of *H. martini* Kirk.

Habitat. Uhler said that "it sometimes lives in the dirty holes, among the duckweeds, *Lemna,* where it wanders about over the green

algæ and slime floating on the surface, the color of which it matches in the young stages." We have found it on the Sphagnum at the edge of bog ponds in New York, and amidst the Typha, smartweed, spike-rush, etc., growing in the shallow pools and ponds of Kansas, as well as upon floating rafts of dead typha, or tangles of Spirogyra. It prefers the footing such supports may offer to the open water. However, it can walk upon the water when occasion demands.

Hibernation. It winters as an adult in the trash about the pool, coming out in early spring to resume activity. Wesenberg-Lund, 1913, says that the species of Denmark winters in damp moss.

Mating. There is some difference in the size of the sexes of this bug, the male being smaller than the female. Martin says that the peculiar habitat of this bug, combined with its elongate form, has given rise to a secondary sexual character, which occurs in the *H. stagnorum,* as well as in our own species. This consists of two notched projections on the under side of sixth abdominal segment, close to the incisure between the sixth and seventh segments. (See pl. XIII, figs. 8 and 9.) The first of these notched elevations of the abdominal walls, he says, is to fit over the lateral keels of the female abdomen, thus steadying the abdomen of the male during copulation.* This is rendered necessary not only by the elongate abdomen, but also by the fact that it is necessary for the insects to maintain their balance upon the water or run the risk of breaking through the treacherous surface film.

Oviposition. Martin has given us a splendid account of the oviposition of this bug. The writer has often seen the same process. The female "exudes from the genital opening a drop of gummy gelatinous substance, which she then presses against the object that has been closen to support the egg. This sticky mass is the base of the egg stalk, and hardening very soon, fastens the egg in place before it has left the body. The insect now walks away from the stalk, thus freeing herself from the egg."

The newly laid egg is creamy white, which after about half a minute quite suddenly changes to a brown, the ends remaining lighter than the body of the egg. The material with which the egg is attached appears shiny and fluid for several minutes.

The female places her eggs upon any support, a little above the surface of the water as a rule. In the aquaria the eggs were placed upon the vertical sides of the glass jars from the water level to two inches above it. In nature the writer studied a colony of these insects that were living on the shallow waters of a pool overgrown by cattail. It was early April. The cattail seeds were sending out long sprouts, forming a green mat upon the water. The marsh-treaders were laying their eggs upon these sprouts. The brown spindle-shaped eggs are much the color and shape of the cattail seeds, which gives them a striking superficial resemblance, which is shown in the photograph on plate VI.

Incubation. Martin gives 17 days for the duration of the egg stage. Bueno says from 19 to 9 or 10 days. In Kansas, eggs laid the afternoon of July 16, hatched July 20 in the afternoon, a period of four days!

* Have observed mating often, but these processes were not used.

Seven days represented the average for 53 eggs in July. The red eye spots appear in such a period about the third or fourth day. A few eggs required 23 days to hatch in May.

Hatching. The hatching process had not been recorded for our American forms, and the writer was delighted for the opportunity to study the process in detail. Notes and drawings were made at the time, and are given herewith. While at Ithaca, N. Y., there was available in the private library of Mr. J. T. Lloyd, a set of the "Annals de Biologie Lacustre." In volume IV, page 327 (1911), Brocher, under the title "Observations biologiques sur quelques insectes aquatiques," gives an account of the oviposition, the egg and the larva of "Lemnabates." He figures the egg and the postnatal molt of an escaped nymph. In hatching, the body of the egg swells in one spot and gradually the shell begins to split longitudinally down one side. The embryo bulges through and in a few moments the red eye spots come to view and the shiny black "eggburster" of the embryonic envelop (postnatal molt) shows between the eyes. (See pl. XIII, fig. 7.) Gradually with slight bulging movements the embryo works its way out until it occupies a position almost at right angles to the egg shell. It is still inclosed in the thin membranous envelop. The envelop now splits at the cephalic end (pl. XIII, fig. 10), and as it is cast the antennæ and legs gradually appear uncovered though still folded against the ventral side. The head (so long and slender in the hatched bug) is bent at a position caudad of the eyes so that in the embryonic envelop the most of the head is folded on the ventral side of the embryo, the beak reaching nearly to the caudal end. One of the eggs observed during the hatching was just beneath the surface of the water and the embryo coming forth was partly below and partly above. Yet when the antennæ were liberated and the head allowed to straighten and the limbs freed, the tiny almost transparent pale green nymph had little trouble in arriving at an upright position on the surface film.

Behavior of Newly Hatched. The newly hatched bug can walk upon the surface of the water and is soon ready to look for something to eat. It begins the precarious existence of the surface dwellers. A close study of these creatures as they go about their daily activities in field and laboratory, brings home to one the tragedy of life with its grim "survival of the fittest." We were watching one nymph disengage itself from its shell. It was a slow laborious process, this particular coming into the world. We were relieved in a way when its postnatal molt was completed. Yet this feeling was short lived, for hardly had this new life righted itself upon the surface film and taken an inventory of its surroundings before there stalked up behind it, as we watched, another tiny nymph. This second fellow was a little darker (he had hatched a few hours before). Slowly but with definite purpose this murderous nymph slipped up behind the unsuspecting newly born, with beak outstretched before it. A sudden movement, and with a squirm of distress the little bug we had watched come into the world was caught upon the stylets of his brother, and its brief life of a few moments was over. Such is the life of the pool! Then, as we watched, its poor body became the banquet table of two of its brothers. One with its beak inserted in the joint between the femur and

the tibia of the foreleg, and the other drawing forth the body juices through the beak inserted just behind one eye. Many a young marsh-treader meets such a fate! Only a few minutes are required to crumple the little body down to a shapeless form.

Number of Instars. There are five nymphal instars, as has been noted by Martin. These have not heretofore been described, however, and great difficulty and confusion resulted in the writer's first attempts to do so, due to the fact that length within the instars varied so greatly. At last, by the use of limb measurements which are fairly constant, it was possible to make a description that could be applied for the identification of material taken in the field. All the rearings were apterous when mature.

Maturity. Bueno has given us the time between mating and oviposition, but not the time from emergence to oviposition. He mated a virgin female July 26 and on the 28th or 29th it laid the first egg. The entire period from emergence to egg laying need occupy but two days.

Fecundity. The peculiar shape of these insects and the relatively large eggs (see pl. XIII, fig. 15) has led to the belief that reproduction is not very rapid. To determine this point the writer carried out numerous isolations. Here is the story of a stender dish containing eight females and one male. The bugs were placed here July 8, and the eggs were counted and removed from time to time.

July 8, p. m.........	6 eggs removed.
July 16, a. m.........	127 eggs removed.
July 16, p. m.........	6 eggs removed.
July 17, p. m.........	53 eggs removed. 2 females dead; 6 females remain.
July 18, p. m.........	18 eggs removed. Male escaped.
July 20, ——........	22 eggs removed.
July 26, ——........	135 eggs removed.
July 28, ——........	2 females dead; 4 females remain.
July 29, ——........	13 eggs removed. 1 female dead; 3 females remain.
Aug. 2, ——........	No eggs removed.
Aug. 4, ——........	1 female dead; 2 females remain.
Aug. 5, ——........	46 eggs removed.
Aug. 6, a. m.........	13 eggs removed.
Aug. 7, a. m.........	10 eggs removed.
Aug. 11, p. m.........	42 eggs removed. 1 female dead; 1 female remains.
Aug. 31, p. m.........	30 eggs removed. Drop experiment.

By keeping in mind the number of females involved during each period we get an average of 3.6 eggs per day laid by each female from July 8 to August 31. The first 9 days the 8 females laid 192 eggs, an average of 2⅝ plus, each per day. The next day 6 females laid 3 eggs each, and for the 10-day period laid 175 eggs, which was very nearly an average of 3 eggs per female each day. August 6, 2 females laid 13 eggs, and the next day, 5 each. This remarkable record was continued for the next five days. The production then declined. In another jar one nymph was placed. This became an adult female August 1. On the 5th there were

four eggs; on the 6th, 11 eggs, on the 7th, 17 eggs. By August 31 this unfertilized female had laid 47 eggs. These eggs were left under the observation of a friend to determine whether any would hatch. They were forgotten. In the case cited above where 8 females and 1 male were placed, the male escaped July 18, but the females continued to lay fertile eggs. In a third jar an egg hatched July 13. An adult female came forth July 25. Placed a male with her and by August 4 there were 28 eggs, which were removed. They were mating on this date. The evening of August 5 there were 11 eggs. All of these were placed at the water line. August 14, 78 eggs were removed. This one female in 10 days laid 78 eggs. The male died on the 22nd, and the rearing discontinued on August 31, when 67 more eggs were removed—a total of 173 eggs in about 36 days. The female was lively at the time the observations were stopped. Thus it will be seen that these bugs lay many eggs and are capable of laying as many as 11 in 24 hours.

Longevity. The adults live a full season and no doubt longer. More data on the longevity of the water bugs is to be desired.

Food Habits. Kirby, 1892, made the unfortunate statement that their "habits were probably herbivorous." A little patient observation would have dispelled such a notion. The measured deliberation of these insects in their undisturbed movements is not conducive to a quick determination of their habits. One summer the writer made the practice of spending a few hours each day in the observation of the normal activities of the bug population of the pool. A three-foot "two by four" with a piece of board nailed on one end, served as a stool that could be carried about in the shallow waters and made quiet and continued observation possible. It is only in such a way that one can make satisfactory notes upon these insects.

As stated by writers from the beginning, these bugs are carnivorous. Kirkaldy was puzzled to note that the fore limbs were not modified for the prehension of their prey, but the writer has shown that the strong and retrorsely barbed stylets are quite sufficient for the retention of their victim. This same morning several were seen with newly emerged and still white midges. He found that the source of their food supply in the main comes from organisms beneath the surface. Ostracods at the surface film, mosquito wrigglers and pupæ, and even Corixid nymphs have been speared out of the water. Bueno noticed aquarium specimens putting out their hairlike rostra and penetrating the surface film with them. A closer study of this would have lead him to some interesting observations. In the field, the early morning is a splendid time to watch them. On one pool where they were living upon a floating mass of dead cattail leaves they were frequently observed. We offered them mosquitoes, but although they might fall within a centimeter of them, they might investigate indifferently but promptly turn their attention to the things that were taking place at the surface film. For the activity here they were all attention! In one case a third instar *N. undulata* came to the surface near an adult female. She dipped her rostrum and antennæ and stealthily approached. Would she hook into this creature? It surely would capsize her for she was upon open water. Now a moment's survey with the beak

ready for action, and then quite suddenly she decided the task too much for her frail limbs and their unsteady support upon the water, and turned away.

In the laboratory with a movable armed binocular the bugs can be watched most satisfactorily. The notes of a few observations are given here. In one case a third instar nymph was watched as it caught an Ostracod resting at surface film. The nymph stalked slowly up to the prey, its body all aquiver and weaving from side to side. The tips of its antennæ were turned down to the surface. The beak directed down and slightly forward. When close to the Ostracod a sudden move and the little Entomostracean was caught and carried away upon the tip of the beak. It was kept free from the supporting surface. Under the binocular the stylets could be seen playing about in the body of the victim, darting and bending around as if to ream out every available bit of nutriment. One half of the tip segment of the beak was pressed between the valves near their hinge. The movements of the stylets were also splendidly shown one time when an adult female bug caught a mosquito wriggler. The wriggler came to surface for air a centimeter away. This excited the marsh-treader greatly. She turned her antennæ to the water surface, and cautiously advanced until the position of the wriggler was located. The beak was then let down slowly into the water and turned forward, imperceptibly approaching the respiratory tube of the larva. All at once a tiny thrust was followed by a sudden but brief struggle of the harpooned wriggler. It was as effectively caught as a fish upon a spear. Five minutes later the wriggler still had a little life. The beak of the bug was inserted near the base of the respiratory tube. The stylets are capable of tremendous exertion. When the tip of the beak has found its prey, the slender flexible stylets are let out at unbelievable lengths in a search for a vulnerable place in the chitinous armor of the mosquito larva. The long head of Hydrometra is necessary to accommodate the play of such long spears. As noted above, the bugs as soon as hatched become competitors, and captors as well, of their fellows. Often a chain of two or three little dead fellows each with his beak in the next one, has been observed, a silent testimony to the fact that while one nymph was interested in feeding upon a new-born brother, his own happiness was ended by an attack from behind.

DESCRIPTION OF STAGES.

The egg has been splendidly figured by Martin, but our own figure was made before we discovered the drawing by Martin.

Size. Length, 2.07 mm.; greatest diameter, .277 mm.

Shape. Very long and spindle shaped. The slender stem at the base of the egg set into a little button-like pad attached to the support.

Color. Brown. The spindle-shaped ends lighter than the body. Markings consist of longitudinal flutings over the body of the egg and lacings at the end, as shown in the drawing on plate XIII. One-fourth of the total length at each end is taken up by this lacing. This leaves one-half the entire length of the egg covered by the flutings. The entire surface is punctate.

First Instar.

Size. Length, about 1.3 mm.; varies greatly. Width of body, .216 mm.; length of head, .5 mm. The length of antennæ, 1.49 mm. Fore leg, 1.33 mm. Middle leg, 1.33 mm. Hind leg, 1.96 mm.

Shape. More robust than later instars; given to turning tip of abdomen up as the Staphylinids do.

Color. Body glassy with very faint greenish tinge. Just a hint of darker pigment on the thorax, and a sprinkling of cinnamon on sides of abdomen of older nymphs. Legs and antennæ faintly amber brown. Eyes coarsely granular, hemispherical and red, situated approximately half way between insertion of antennæ and its union with prothorax.

Structural Peculiarities. The head is widest back of the eyes where the lateral tubercle gives off a lateral bristle. The narrowest width of the head is at the constriction just in front of the eyes where the head is only .125 mm. wide. The width across the eyes is .208 mm. The beak reaches nearly to middle coxæ. Abdomen consists of 9 segments. The basal segment of the antennæ carries a few bristles, second segment several, while the third and fourth are thickly covered with short hairs. The femora are sparsely clothed with short spiny hairs, while the tibia bears many, and the single tarsal segments are densely clothed with them.

Second Instar.

Size. Length, tip of head to tip of hind femur, 1.75 mm.; width of body, — mm.; length of head, — mm.; length of antenna, 1.59 mm.; fore leg, 1.345 mm.; middle leg, 1.5 mm.; hind leg, 2.125 mm.

Shape. General shape as in adult.

Color. Pale straw in general color. Tiny flecks of rust red on sides of body and abdomen. Tarsal segments all dark.

Third Instar.

Size. Length, tip of head to tip of hind femur, 3 mm.; width of body, — mm.; length of head, — mm.; length of antennæ, 2.13 mm.; fore leg, 1.7 mm.; middle leg, 2.05 mm.; hind leg, 3.03 mm.

Color and Shape. As in other instars.

Fourth Instar.

Size. Length, tip of head to hind femur, 4-4.5 mm.; width of body, .406 mm.; length of head, 1.38 mm.; length of antennæ, 2.952 mm.; fore leg, 2.7 mm.; middle leg, 3 mm.; hind leg, 4.1 mm.

Shape and Color. As before.

Fifth Instar.

Size. Length, tip of head to tip of hind femur, 6 mm.; width of body, .47 mm.; length of head, 2.25 mm.; length of antennæ, 3.54 mm.; fore leg, 3.8 mm.; middle leg, 4.37 mm.; hind leg, 6.44 mm.

The tarsi are all one-segmented in the nymphs, three-segmented in the adult; roughly the various instars can be separated on basis of the length of hind leg, 1 mm. 2+, 3+, 4+, 6+, for 1st, 2d, 3d, 4th and 5th instars respectively. The newly-emerged adults are pale greenish in color, darkening gradually.

Summary. In addition to the notes made by Martin and Bueno, the writer has been able to determine that while they may feed upon insects trapped upon the water, their main supply comes from emerging midges, Ostracods and mosquito wrigglers. They respond much more quickly to the activity beneath the surface than to that above. They may lay 175 or more eggs and as many as eleven in one day. The average time for the incubation of the egg is 7 days, with a range from 4 to 22 days. Each nymphal instar requires on the average 2 days. Sometimes three or four, and in a couple of cases, only one day. The complete cycle from egg to egg, under the most favorable conditions, lasting 15 days.

Family MESOVELIIDÆ D. & S. 1867.

A. Taxonomy of Mesoveliidæ.

Description. These are small, rather slender, green or yellowish-green bugs. The adults may be winged or apterous. (In the latter case the adults are distinguished by a broad connexvium.) Antennæ four-segmented, filiform. Ocelli are present in the winged adults but "obsolescent" in the wingless forms. Rostrum three-segmented, tarsi three-segmented. One genus, embracing one North American species.

Historical review. Since these bugs were first made known to science in 1852 by Mulsant and Rey, through the descriptions of *Mesovelia furcata*, there have been added a few other species. Among them one described by F. B. White from the Hemiptera collected in the Amazons by Prof. J. W. Trail and named *Mesovelia mulsanti.* Uhler gave to our American species the name of *M. bisignata* and speaks of it at some length in Kingsley's Natural History.

Van Duzee regards this *M. bisignata* as a synonym of *M. mulsanti* White.

The phylogenetic relationship of this little group has been somewhat of a puzzle. Mulsant and Rey assigned the genus to the family Hebridæ. Dohrn, 1857, in his Catalogus Hemipterorum places the Hebrids and Mesoveliids together under what he calls "Ductirostri" between the Mirids and Tingidids. Baerensprung, 1860, in the "Catalogus Hemipterorum Europæ" includes the Gerrids, Veliids, Hebrids and Hydrometrids in the family Hydrometridæ. Douglass and Scott, 1867, were the first to disengage them from the others. These writers set them apart with tribal rank. On the whole, writers assigned them to kinship with the various waterstriders and treaders until Reuter, 1912, removed them to a position with the Hebridæ between the Reduviidæ and Nabidæ.

General Habits. These insects are to be found upon and about the blankets of algæ, duck meat, etc., floating upon quiet pools. They take to the open water when disturbed, where they are able to propel themselves with a fair degree of success, running upon the water rather than rowing, as do the Gerrids.

Genus MESOVELIA M. & R. 1852.

Besides the characterization given under the family description, and in the absence of the original generic description, there is little that the writer dares to hazzard concerning the generic description. The pro-

longation of the head before the eyes is certainly of generic value at least.

Mesovelia mulsanti White 1879.

Trans. Ent. Soc. London, vol. 17, ser. 3, p. 268.

"General color yellowish testaceous to green. The gibbous hind lobe of the prothorax lead color, marked with a yellow stripe along the middle; the outer sides and tip of the scutellum, the veins and cuneus of the wing-covers, the eyes, the tylus, the apical joint, points of articulation, base, a few marks in the antennæ, a large part of the end of the tarsi, and the tip of the tibiæ, are brown. The underside of body clothed with a close silvery pile.

"Antennæ are slender, filiform, longer than the abdomen, the basal joint is barely a little thicker than the others, of about the same length as the third and fourth, the second joint much shorter than the others, and the antenniferous tubercles are expanded in front so as to give a trumpet-like enlargement to the front of the cranium. From the slightly bent clypeus the slender rostrum extends back to the middle coxæ, the second joint being long and tapering. The prothorax is contracted into a short, transverse front lobe, but widened at the shoulders, which are tubercle-like and prominent, and the posterior margin is cut almost square off; behind this the scutellum is conspicuous, and has a triangular, callous elevation on the disc and a smaller one behind it."—*Uhler*.

Distribution: Massachusetts, New York, New Jersey, Maryland, North Carolina, Florida, Ohio, Illinois, Kansas and Texas.

The specimens that have come under the writer's observation conform in a number of other points not mentioned above. The head is large before the eyes and bears four black shiny setiferous tubercles, two on either side of the median line, some distance in front of, and on a line with, the inner margins of the compound eyes. A similar pair lie in the back part of the head laterad of the ocelli and on a line with the posterior margin of the eyes. These are found on both sexes, apterous and winged, and upon the nymphs. The adults also have a median longitudinal groove extending from the clypeo-frontal suture to the caudal margin of the head.

The female abdomen is much wider than that of the male and in profile very different (see pl. XIV).

Champion states that Uhler's bug checks with White's description, and since there is still some question regarding the species, the original description is here appended "in toto."

M. mulsanti White.

"Sordide flavo-testacea, subopaca, plus minus fusco-nebulosa; clypeo, ocellis, pronoto marginibus angustissimis foveisque lobi antici et lobo postico, scutello marginibus et maculis literam C simulantibus in utroque latere disci plagæ anticæ sitis, hemelytris venis, tarsis articulo ultimo, necnon spinulis pedium plus minus nigro-brunneis; antennis articulis 1° 2° que ad apicem, 3° 4° que totis, tibiis ad apicem, tarsorum articulo 1° et articulo 2 ad apicem fusco-brunneis; hemelytris albidis, corio cellulæ interioris dimidio apicali, clavo margine apicali et margine interiore pone medium necnon macula discali fuscis; capite antice albopiloso, macula utrinque prope basin antennarum fusca, et macula minore utrinque pone illas nogro-brunnea; pronoto lobo postico linea longitudinali flavo-testacea notato, angulis posticis emarginatis; scutelli plaga antica fovea semicirculari utrinque instructa; hemelytrorum membrana vena fusco-brunnea subsinuata, ex apice cellulae interioris corii ad

angulam apicalem interiorem membranæ currente et membranam a clavo separante, instructa, (membrana interdum obsoleta); corpore subtus albido-testaceo, albo-piloso.

"Long. 4 mm."

B. Biology of Mesovelia.

General Notes. Since there is probably but the one species of the genus in America, any discussion of the general habits must be based upon the two species observed. They are small insects, that measure but four or five millimeters in length. The young and apterous forms of the adult display varying degrees of green coloration, while the winged ones are quite conspicuous in the floating blankets of green algæ because of the silvery whiteness of their wings.

They are at home in the haunts of the marsh-treader, on the floating vegetation growing in the shallow water of pools, where the clumps of sedge spread their slender stems upon the water from the bordering bank, where young cattails spring up and green algæ carpet the surface of the waters.

The information concerning the biology of these forms is meager and confined to a paper by Butler, 1893, on the "Habits of *Mesovelia furcata,*" collecting notes on *M. furcata* by J. Scott in England, and on the *bisignata* (Mulsanti) by Uhler and by Bueno in this country. The writer published a paper in *Psyche* for June, 1917, from which most of the facts here presented were gleaned.

Habitat. *Mesovelia mulsanti* lives upon the floating vegetation of ponds. Butler found them on Potamogeton and Bueno on duck-weed, matted Hydrodictyon or other algæ. The writer has found them about old logs projecting from the water, clumps of smartweed at the water's edge, as well as on rafts of filamentous algæ and the leaves and stems of such plants as water shamrock, procumbent upon the surface.

Hibernation. Direct evidence upon this point is lacking, for in winter collecting at Ithaca, N. Y., none were taken. On November 8, 1916, on a trip to Ringwood Hollow, in company with Mr. Lloyd and Dr. and Mrs. Needham, two apterous adults were taken by the writer beside a large moss-covered log lodged in the shallow waters of the winter-berry pool. This would indicate that they winter as adults. They did not come to the writer's attention till May 25, 1916, at which time the green scum of Cattail pool, near Lawrence, Kan., was swarming with hundreds of nymphs just coming to the adult stage. These appeared to be the progeny of over-wintering bugs.

Food. They were noted by Butler to be carnivorous in tastes. He fed them a variety of small insects and saw them feeding upon a springtail (Smynthurus), a Crambus, a Chalcid and a Hydrometra, and supposed the usual food to be small Diptera and Hymenoptera. As to whether they caught their prey alive or availed themselves of the drowned and disabled specimens he was unable to say. That *M. mulsanti* can live upon such fare is certain, for the writer has reared them on flies and plant lice cast upon the water.

They are cautious creatures, but do on occasion fall upon fairly lively prey, as evidenced by the following instance: A fly thrown into

the aquarium was seen to crawl up the side of the jar bearing an adult female *Mesovelia* with its beak attached near the caudal end of the fly, which when disturbed flew to a nearby support, bearing the tenacious little bug.

However, the writer has come to believe that, with Hydrometra, Microvelia and Rheumatobates, they are not dependent upon the chance and uncertain fare of terrestrial insects caught upon the surface film, but find another, and indeed a more constant source, in the organisms that dwell below but come up to the surface film. Among these, Ostracods and like forms are available as more or less staple food and Mesovelia have been observed exploring the sides of floating Typha and the tangled mats of algæ for such Crustacea which they spear from the surface of the water.

The tiny nymphs feed upon more gentle organisms in the water, as there are few upon the surface that they are able to overcome. When offered springtails, as suggested by Butler, disaster often followed, and the writer lost many good rearings before he learned the inadvisability of offering such food. The hungry little creatures would attack them, only to be turned topsy-turvy upon the water, even by comparatively small springtails. Plant lice afforded less risk of this kind and gave better results. They were used as the food supply in the isolation rearings where a study of molts was made. But in an aquarium 12 inches in diameter, the water of which contained algæ and floating sedge stems amongst which dwelt an abundant population of Entomostracans, the little bugs were reared through their complete cycle without other resource than that afforded by the waters and the weaker of their own kind.

Mating. In mating the male mounts the female, clasps his fore legs around her mesothorax in front of her middle legs, rests his middle legs upon the water film or other supporting surface, and holds the hind legs poised in the air. The copulatory organ of the male is long and curves around the side of the tip of the female's body to come into contact with the genital opening. Contact lasts from a few seconds to one minute or longer. Upon withdrawal the copulatory organ is seen to be a slender white tube of astonishing length.

Oviposition. Since Mesovelia hides and protects its eggs by burying them in the tissues of certain plants that are associated with shores and shallow waters, the female possesses an ovipositor adapted to this purpose. If the female be examined in lateral view, the abdomen is seen to be laterally compressed at its caudal end in such a manner as to provide a sheath or groove for the ovipositor. A dissecting needle inserted near the distal and caudal end of this fissure can be used to pry out and bring to view a shiny brown chitinized organ which may be turned down into a position approximately at right angles to the body, for its attachment is at the basal end of the sheath. In this position it is seen to be curved so that the tip is directed slightly forward. The general shape, viewed from the front, is roughly spear-shaped and the parts arranged in such a way that the front surface is concave, form-

ing a wide groove, reminding one, when in action, of the tip of an apple corer. Upon dissection it is seen to be made up of three parts, two lateral shafts that are strongly chitinized and toothed or serrated along the lower portion of their lateral margins and a broader central plate. The lateral shafts are attached to the flat plates of the abdominal wall. The central portion is in reality made up of paired parts attached to the median pair of sclerites that serve as the valves or shields for the ovipositor.

The manipulation of this instrument during oviposition may be observed any time during the spring, summer or autumn by confining a number of mating insects in a petrie dish containing only clear water and some food. After being thus deprived for a couple of days of materials in which to place their eggs, they will gather about a small bit of sedge stem or cattail leaf supplied them, and most eagerly set about the business of laying eggs. The writer has seen as many as eight thus employed about a portion of sedge stem one and one-half inches long, and has had ample opportunity to watch the process under the binocular.

The female frequently explores the stem with the tips of her beak and antennæ if indifferent in the matter, but if eager to oviposit, she mounts the stem without delay, raises the abdomen slightly, unsheaths the ovipositor and turns its tip down to the surface of the stem. At times the surface is tested out at several points—again if the first point of contact is favorable, the tip is caused to quiver back and forth till it gains a footing, and then rocking the body slightly from side to side the entire drill is caused to rotate or twist back and forth on its axis, rapidly at times, or again more slowly as may suit the necessity of the work, until a hole is effected and the ovipositor is buried to its base. During the deeper drillings the longitudinal alternate thrusts of the drill parts are apparent. The first part of the operation at least involves much the same sort of motion as one employs in making a hole with a gimlet or awl. It takes but a moment in the spongy, water-soaked stem of a sedge to drive the instrument up to its base. Then, after a moment of apparent quiet, the ovipositor is lifted slightly and the egg is forced by a series of abdominal contractions down the ovipositor and into the cavity reamed out to receive it.

The egg when forced into the ovipositor distends it considerably as it passes through its channel and thus can be seen to slip down into position with its distal end directed forward beneath the insect. The ovipositor being at last withdrawn from beneath, the egg slips out from behind the exposed circular end of it.

A number of eggs may be imbedded thus, in the stem, before the ovipositor is sheathed, each one requiring a separate puncture. In the cylindrical stems of plants procumbent upon the water the eggs are likely to be inserted on the sides as they come in contact with the surface film, but this is by no means necessarily the case.

As frequently as not the male accompanies the female during the process. Having mounted her in mating, he merely moves forward and

remains perched upon her back as she busies herself with egg laying, mating being attempted and often consummated between her labors.

In starting the drill in a particularly stubborn or inconvenient place the female not infrequently uses one of her hind legs to steady and stiffen or support the drill. One female after making several attempts employed her right hind leg in such a manner that the tarsus was turned at an angle with the tibia and the angle thus formed used to direct and aid the ovipositor.

During the process of oviposition the female often defends herself from molestation by kicking vigorously with the hind legs when disturbed.

Incubation. The egg stage lasts seven to nine days. The deep red eye spots are visible two days before hatching.

Hatching. At hatching the young nymphs, still enclosed in their embryonic membrane, work their way up through the little circular openings of the stem. This is a remarkable feat, considering the size of the nymph and the size of the hole, but is aided materially by the peculiar backward pointed pegs on the thin embryonic membrane. When well out of the stem, this membrane is cast and the nymph takes its place upon the water.

Number of Instars and Molting. There are five nymphal instars. Molting takes place upon a support of floating material or even upon the water itself. The ruptures of the integument take place along the same lines as for Gerrids.

Maturity and Fecundity. After passing through the five nymphal instars, spending two or three days in each, mating occurs and oviposition begins about the third day. One female emerged August 1, began to lay August 3, and died August 12, having laid 44 eggs, an average of nearly five eggs per day. Some of the females in isolation laid an average of less than this, while one female under observation laid 18 eggs in 24 hours, a surprisingly large number, considering the size of the egg and adult.

DESCRIPTION OF STAGES.

The Egg.

Size. Length, 0.875 mm.; greatest diameter, 0.187 mm. to 0.250 mm.; diameter of exposed circle, 0.15 mm.

Shape. The egg is elongate-oval, with a curved neck terminating in a flat surface which marks the exposed end of the egg as it lies *in situ* in the stem of some plant.

Color. When first laid, white; in the course of two or three days it has become watery transparent, with portions of the embryo beginning to take form. These eggs are buried singly. The exposed end of the egg shows up as a shiny membranous circular spot on the surface of the plant which bears it and is visible to the naked eye. This spot, though clear white when first laid, presents at about the second day a very faint ring of pink which darkens to a deep pink after 25 hours. In the course of another day or two this gradually fades, and two days before hatching the deep red spots may be seen through clear stems.

First Instar.

Size. See the table presented below.

Color. When first hatched it is white, with red eyes darkening to amber and green as it ages. To the unaided eye it is greenish brown. Thus it is much darker than the older nymphs, quite distinct in coloring. The tips of the appendages are dark, while the limbs themselves are pale.

Structural Peculiarities. The general form is stouter and more robust than that of the later stages. The body and limbs are clothed with hairs and bristles. The head and thorax bear a few stout bristles and the antennæ bear on the first segment several (usually three or four) stout bristles directed mesally and the terminal segment is thickly covered with fine hairs. The limbs, besides bearing many hairs, possess a number of black bristles arranged as follows: One stout bristle is prominent near the distal end on the anterior margin of the meso- and metathoracic femora. The metathoracic tibiæ are beset with numerous irregularly arranged bristles, terminating with one larger than the others.

The antennæ are stout and as long as the body, four-segmented, the terminal segment is somewhat broadened and as long as the other three. The head bears no indication of ocelli, but does possess the black bristles indicated in the later instars.

The limbs are stout, the tarsi one-segmented and end in two claws.

The abdomen bears a dorsal pore on the median line of the dorsum of the fourth abdominal segment.

Later Instars.

The second and later instars are bright green in color and more slender in form. They possess relatively fewer hairs on the body, but retain the black bristles in the positions indicated in the first instar. There appear in these later instars one black bristle on anterior margin of fore femur and two on the other femora. The structural characters remain constant until the adult stage is reached, when the following changes become apparent:

The first antennal segment possesses but one black bristle instead of a number of them (usually).

The limbs are more slender and tarsi three-segmented.

The connexivum is broad and the sexual characteristics appear.

In the winged female there appear two dark ocelli-like spots on the vertex.

The winged forms are often found with membrane missing. They have been observed to break away this portion of the wing with the hind tibia, exposing the tip of the abdomen.

Following is given a table of measurements of the various instars and of the adults:

TABLE OF MEASUREMENTS IN MILLIMETERS OF INSTARS OF MESOVELIA MULSANTI.

Stage.	Measurement from tip of femur to tip of femur......	Antennæ.				Hind leg.			Middle leg.			Fore leg.		
		1st seg.....	2d seg.....	3d seg.....	4th seg.....	Femur.....	Tibia.....	Tarsi.....	Femur.....	Tibia.....	Tarsi.....	Femur....	Tibia.....	Tarsi.....
1st instar....	1.	.149	.099	.11	.416	.416	.573	.211	.336	.306	.166	.25	.213	.129
2d instar.....	1.25	.20	.125	.20	.5	.54	.625	.225	.35	.343	.188	.312	.26	.135
3d instar.....	1.5	.25	.166	.207	.54	.625	.85	.275	.437	.44	.225	.375	.33	.167
4th instar....	2.125	.29	.21	.32	.75	.81	1.	.375	.625	.625	.29	.5	.38	.25
5th instar....	2.5	.375	.29	.375	.81	1.03	1.37	.437	.75	.75	.375	.625	.50	.26
6th (male)...	......	.65	.416	.716	.96	1.35	1.56	.5	1.09	1.09	.416	.858	.75	.26
6th (female)..	......	.59	.39	.65	.79	1.56	1.95	.65	1.17	1.17	.52	.91	.78	.312

Summary. Mesovelia mulsanti is found about the margins of ponds and pools upon floating vegetation where it feeds upon small organisms coming to the surface film from below or that fall upon it. The species probably passes the winter as adults that begin ovipositing in the spring. They place their eggs in the stems of plants and even in the spongy wood of floating logs. There is a succession of generations throughout the season, each cycle requiring about 24 days. Winged and wingless forms occur together. Besides flying from pool to pool, they may be transferred in the egg stage. Mr. Beamer sent them from the southern part of the state to the writer at Lawrence, Kan., in the stems of sedge used as packing for some Naucorids.

The general distribution of this species, and the ease with which it may be controlled and observed both as to oviposition and to hatching, make it a valuable object for studies on many phases of animal behavior.

Family GERRIDÆ. Am. & Serv. 1843.

Amyot and Serville, Hemip. pp. 1, 410, Groupe Gerrides.

A. Taxonomy of Gerridæ.

Family Characteristics. Long-limbed bugs that live upon the water. The antennæ are longer than the head and exposed, 4-segmented. The head is shorter than the thorax including the scutellum. The limbs are slender, the tarsi covered by close set pile and the claws of at least the front pair distinctly anteapical with the terminal tarsal segment more or less cleft. The hind femora extend beyond the tip of the abdomen; the intermediate and hind pairs of legs approximated, very distant from front pair; ocelli present, but sometimes very obscure; eyes close to the anterior margin of prothorax. Rostrum 4-segmented, first and second segments short; tarsi 2-segmented; parts of hemelytra more or less confluent, often wingless.

Historical Review. The name Gerris was so promiscuously used for various bugs by the early writers that Stal thought to help matters by substituting other names. So many of us have known these bugs as *Hydrobatidæ.* It may be of interest to note that the name *Tipula* now in

the Diptera was probably applied to some of these bugs. The Gerrids are allied to the Veliids and have often been placed together, with others, in the family *Hydrometridæ.*

KEY TO THE GENERA OF GERRIDÆ.

A. Inner margin of the eyes accurately sinuate behind the middle. Body comparatively long and narrow, abdomen long.
  B. Pronotum sericeous, dull, antennæ comparatively short and stout.
    C. First segment of the antennæ shorter than the second, and third taken together.
      D. Antennæ as long as half the body; sixth abdominal segment of the male roundly emarginate. *Limnoporus.* (1 species.)
      DD. Antennae not as long as half the entire length of the insect, not extending beyond the thorax; sixth abdominal segment of male doubly emarginate. *Gerris.* (9 species.)
    CC. First segment of the antennæ longer than the second and third taken together. *Gerris.* (subgenus *Aquarius.*) (4 species.)
  BB. Pronotum glabrous, shining; antennæ long and slender. *Tenagogonus.* (3 species.)

AA. Inner margin of the eyes convexly rounded; body comparatively short and broad, abdomen so short as to appear almost nymphal in some forms.
  B. First antennal segment much shorter than the other three taken together; not much longer than the second and third taken together, and sometimes shorter.
    C. Fourth (apical) segment of antennæ longer than the third.
      D. Eyes larger, fairly prominent; colors black and yellow. *Trepobates.* (1 species.)
      DD. Eyes smaller, widely separated; plumbeous forms, entirely sericeous. *Halobates.* (2 species. Ocean dwellers.)
    CC. Fourth segment of antennæ never more than equal to third; basal segment of anterior tarsi much shorter than second; hind femur equal to or much shorter than hind tibia and tarsus taken together. *Rheumatobates.* (3 species.)
  BB. First antennal segment nearly equal to the remaining three taken together, much longer than second and third; antennæ almost as long as entire body; hind femora twice as long as hind tibia. *Metrobates.* (1 species.)

Genus GERRIS Fabr. 1794.

This genus is our largest in the family. It contains 9 species, placed in the two subgenera *Aquarius* and *Gerris*. The former with four species, *G. remigis, G. orba, G. conformis* and *G. robusta*. The latter contains *G. gillettei, G. marginatus, G. argenticollis, G. buenoi,* and *G. canaliculatus.*

KEY TO GERRIS.

A. First segment of antennæ shorter than second and third together. *Subg. Gerris.*

- B. Sixth abdominal segment acutely produced into a spine, comparatively slender species (mostly apterous). *G. canaliculatus.*
- BB. Sixth abdominal segment not spinously produced, stouter species (mostly winged).
  - C. Anterior margin of pronotum with a flavous line; second emargination of sixth male segment roundly rectangular, female genital segment comparatively broad; connexivum dark. *G. buenoi.*
  - CC. Anterior margin of pronotum yellow clothed with thick silvery pubescence. *G. argenticollis.*
  - CCC. Anterior margin of pronotum concolorous; second emargination of sixth male segment narrow and rounded; female genital segment comparatively narrow, connexivum flavus. *G. marginatus.*

    (Note) *Gerris gillettei* L & S is omitted from this series pending further study.

AA. First segment of antennæ as long or longer than the second and third together. *Subg. Aquarius.*

- B. Comparatively stout bugs. The spines of sixth abdominal segment not reaching end of genital plate.
  - C. Male venter, with two large blackish spots on each segment; male venter sulcate down the middle. G. remigis
  - CC. Male venter without conspicuous black patches, shallowly sulcate down the middle. *G. robusta.*
- BB. Comparatively slender, generally winged, spines of sixth segment reaching end of genital segment. *G. conformis.*

  (Note.) *G. orba* omitted for present. Van Duzee says he is not sure he can tell it from *remigis.*

Gerris remigis Say 1832.

Say, Het. N. Harm., p. 35, 1832; Compl. writing Le Conte, vol. I, p. 362.

"Dark olivaceous; thorax rounded behind, without an elevated line.
"Inhabits United States.
"Body dark brownish-olivaceous; thorax transversely rugulose without much appearance of a dorsal raised line; a dull ochraceous and indented line before; posterior margin regularly and obtusely rounded with but a very narrow depressed margin; tergum with a black line on the middle, in which is a series of obsolete gray lines; lateral margin with a series of grayish points or short transverse lines; beneath with a silvery sericeous reflection, an impressed line on the anterior part of the pectus behind the anterior feet.
"Length, half an inch.

"A great similarity exists between some of the species of this genus, and I have ventured to separate this species from the *paludum* F., which is said to have an elevated line on the thorax and another on the pectus and postpectus.

"The thorax on the posterior segment is generally obtusely tinged with dull yellowish, with a blackish longitudinal line in the middle.

"Var. a. Thoracic elevated line rather more obvious; grey lines of the middle of the tergum more distinct.

"Inhabits Mexico."

Champion has given a much larger description in his Biol. Centr. Am. Heteroptera, II, p. 145.

Distribution: Quebec, Ontario, Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Maryland, North Carolina, Georgia, Louisiana, Michigan, Illinois, Colorado, Texas, New Mexico, Arizona, California and Oregon.

Gerris orba Stal. 1859.

Stal.-Freg. Eugen. Resa. Ins., p. 264, 1859.

Distribution: California, Oregon and Nevada.

Gerris conformis Uhl. 1878.

Uhl., Proc. Boston Soc. Nat. Hist., vol. XIX, part IV, p. 435-436.

"Dull olivaceo-fuscus, occasionally a little reddish-brown on the base of the pronotum; form rather more slender than that of *H. remigis*; the eyes more prominent. Pronotum invested with short, dense, olivaceous pubescence, the middle line of anterior lobe impressed orange; the posterior lobe coarsely, deeply, in places confluently punctured, with a slender elevated longitudinal line running along the whole length; lateral edge narrowly yellow. Antepectus pale yellow, powdered with white; under sides of the anterior and intermediate coxæ and outside of the posterior coxæ pale yellow. Medio and postpectus grayish sericeous. Hemelytra blackish brown, not reaching to the top of the ante-genital segment; tergum black, minutely, transversely wrinkled, the connexivum minutely punctured, lateral raised margin yellow, the apical processes slender, acuminate, as long as the segment to which they are attached. Venter cinnereous, sericeous minutely pubescent, the posterior margin of the last segment deeply concave, and together with the under side of the genital segments rufescent. Male: Length to tip of venter, 15-16 mm.; greatest breadth of pronotum, 2¾ mm.

"The lateral margin of pronotum has a stout ridge terminating in a knob on the humerus, and between the humeri are two smaller protuberances, which are sometimes obsolete."

Distribution: Maine, Massachusetts, New York, New Jersey, Maryland, North Carolina, New Hampshire and Connecticut.

Gerris robusta Uhl. 1871.

Uhler, Am. Jl. Sci., ser. 3, I, p. 105, 1871.

Distribution: Reported from California.

Gerris gillettei, Leth. & Serv. 1896.

Lethierry & Severin, Cot. Gen'l Hemip., vol. III, p. 60, (New name for *L. productus* Uhl.). Baker, Hemiptera of Colorado Agri. Exp. Sta. Bull. 31, p. 61.

"Larger and somewhat more robust than *L. marginatus* Say, with long, somewhat flattened, anal processes of a yellow color forming the prolonged ends of the flat, broad connexivum, and is of the same color as the last three segments. Color of the upper surface dark brown with a

tinge of fuscous on the pronotum. Head of medium length, fuscous, covered with silvery, scaly pubescence on the lower sides and beneath. The antennæ short and stout, rusty brown, the second and third joints a little thicker and darker at tip, the second shorter than the apical, but longer than the third, the basal one a little longer than the superior line of head, the fourth a little shorter, dark in color and tapering towards the tip. Rostrum swollen at base, reaching a little behind the anterior coxæ, with the tip black. Pronotum with the anterior lobe quadrangular and flat, a very little shorter than wide, the anterior border a little thickened and raised, the middle line behind this depressed and marked with a short, yellow stripe, the posterior lobe evenly rounded off, a little flattened, destitute of a carinate line, lateral margins narrowly yellow; underside all silvery white. Legs of medium length, pale rusty beneath, the posterior femora as long as from the base of posterior coxæ to the end of venter. Veins of corium prominent, two of the oval medio-apical areoles pale. Sutures of connexivum pale, outer half of the connexivum of the last three ventral segments including most of the segments themselves and the cerci, yellow, the middle line of venter with four indented spots.

"Length to end of anal segment, 10 mm. Width of pronotum, 2 mm. A single female was sent to me from Colorado."

Bueno in Ent. News, XXIV, page 21, has this to say about a female specimen from Garfield, Utah, taken on brackish water.

"This agrees in every particular with the original description and with the type of the collection of the Colorado Agricultural Experiment Station of Fort Collins, kindly loaned to me for study by Prof. C. P. Gillette. This is the first authentic record of the species since it was first described, and serves to establish its character as a good species. Its chief superficial character separating it from *Gerris* (*Limnotrechus*) *marginatus* Say, lies in the anal cerci, which in *marginatus* are short and comparatively stout, while in *gillettei* they are long, attaining the extremity of the abdomen and comparatively slender."

Distribution: Colorado, Utah, Montana, and California.—*Van Duzee.*

Gerris marginatus Say 1832.

Say, Heter. N. Harm., p. 36; Compl. writings, Le Conte ed., vol. I, p. 362.

"Thoras with an elevated line: behind with an obvious depressed margin; abdominal margin dull rufous.

"Inhabits United States.

"Body blackish, more or less tinged with olivaceous; thorax with a raised line, more elevated behind; lateral indented edge dull rufous; posterior depressed margin rather wide and very obvious; abdomen with the margin dull rufous; feet dull rufous; anterior thighs with a blackish line on both sides; coxæ dull rufous beneath; beneath with a slightly elevated line, terminating anteriorly in a depressed one; blackish, with a silvery reflection.

"Length over seven-twentieths of an inch.

"Much smaller than the preceding (*G. remigis*) and more slender, of a darker color; abdominal margin of a different color, and the posterior margin of the thorax is broadly depressed. I obtained an individual, and Nuttall gave (me) one which he took in Missouri."

Localities: Quebec, Ontario, Maine, New Hampshire, Massachusetts, Connecticut, New York, New Jersey, District of Columbia, Virginia, North Carolina, Ohio, Michigan, Illinois, Missouri, Iowa, Kansas, Colorado, Manitoba, California and Oregon.

Gerris argenticollis Parsh. 1916.

Parshley, Ent. News, vol. XXVII, p. 103.

"Dark, velvety brown above with fine sericeous pubescence. Anterior lobe of the pronotum with median and marginal yellow stripes, the former faint, the latter clothed with thick, silvery pubescence; posterior lobe with yellow margins. Inner margins of hemelytra marked at base with white between the veins. Under surface black or silvery, depending on the direction of the light; acetabula, bases of anterior legs and margins of abdomen marked conspicuously with yellow; omphalium and legs, variable, black to pale brown.

"Relative proportions: of antennal segments—1st, 26; 2d, 13; 3d, 12; 4th, 10; of intermediate legs—femur, 50; tibia, 43; 1st tarsal segment, 20; 2d, 10.

"Thorax comparatively robust; abdominal spines not reaching apex of abdomen.

"Male: Fifth abdominal sternite notched at middle of posterior margin; sixth abdominal sternite not carinate, ventral surface of abdomen not distinctly depressed just anterior to genital segment (as it is in *buenoi*), median ventral (second) emargination narrow, semicircular; genital segment narrow.

"Female: Lateral plates of genital segment together very slightly wider than long, widest at middle, carinate ventrally.

"Length from tip of tylus to apex of abdominal spines, male 7.5 to 8 mm.; female, 8 to 8.5 mm.

"Holotype (male) and allotype (taken in copulation) in my collection; paratypes in the Museum of Comparative Zoölogy, Cambridge; Boston Society of Natural History; United States National Museum; and the Academy of Natural Sciences, Philadelphia.

"Described from 10 males and 16 females taken at Forest Hills, Mass., April 26 and May 4, 1915, from a woodland pond, where it was associated with *G. marginatus* Say., and *G. buenoi* Kirk. A female specimen from Southern Pines, N. C., March 15, 1915 (Manee) belongs to this species. This form pertains to the subgenus *Gerris*. It is distinguished from *G. buenoi* and *G. marginatus* by the white markings at the base of the hemelytra, the form of the genitalia,* and the marginal stripes of the anterior lobe of the pronotum which are not silvery in the former and lacking in the latter."

Localities: Massachusetts and South Carolina.

Gerris buenoi Kirk. 1911.

Kirkaldy, Ent. News, vol. XXII, p. 246, 1911.

Bueno, who submitted this paper after the death of Kirkaldy adds:

"This species is a very near neighbor of *Gerris marginatus* Say., with which it has often been confounded in collections. Aside from the correlated structural characters, however, the flavescent margin of the anterior lobe of the pronotum serves to distinguish it at once. It can also be separated by its smaller size, pronounced sutures between the abdominal segments, and more or less flattened abdomen in the male."

Localities: Quebec, Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New Jersey, Colorado and Manitoba.

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* Dr. Parshley gives drawings of the male genitalia of *argenticollis* Parsh., *marginatus* Say, and *G. buenoi* Kirk., ventral view, q. v., in Ento. News, vol. XXVII, p. 103.

Gerris canaliculatus Say 1832.

Say, Heter. N., p. 36, 1832; Comp. writing Le Conte, vol. I, p. 363.

"Above brownish; beneath yellowish, with a pectoral groove extending to the venter.

"Inhabits Georgia.

"Head dark brown, with a slivery line from the eye to the antennæ; antennæ honey-yellowish and feet of the same color, the tarsi dusky; thorax dull yellowish or dull fulvous, darker each side, with a dorsal dull fulvous line and lateral margin, beneath which is a double black line enclosing a silvery one; hemelytra brown with black nervures; tergum fulvous with a black lateral line and yellowish margin; terminal spines even with the tip of the tail; beneath yellowish fulvous; pectus with an obvious groove, extending to the venter, and in which behind is a blackish line.

"Length less than two-fifths of an inch.

"Differs from *marginatus* in having an obvious groove beneath extending to the venter. The whole inferior (surface) also is yellowish, with the usual silvery reflection; the posterior depressed margin of the thorax is not so wide as in that species, and has no raised line."

Localities: Rhode Island, New York, New Jersey, Massachusetts, Connecticut, North Carolina, Georgia, Florida.

Genus LIMNOPORUS Stal.

Represented in this country by one species in the literature. The following points characterize the genus: Body, long and narrow; abdomen, long. Antennæ as long as half the body—the first segment shorter than second and third together. Sixth abdominal segment of the male roundly emarginate.

Limnoporus rufoscutellatus Latr.

Latreille, Genera, Crust. Ins., III, p. 134, 1807.

"The following description from Lamark's Hist. Nat. des Animaux sans vertebres:

"Sufra fusco-nigricans, infra argenteo, sericea; thoracis parte postica, abdominisque lateribus pallido-rufescentibus."

This is a fairly large, slender, dull reddish bug, well marked from our other species.

Localities: Quebec, Ontario, Maine, Massachusetts, New Hampshire, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Maryland, Michigan, Illinois, Wisconsin, Dakota, Colorado, Arizona and British Columbia.

Genus TENAGOGONUS Stal.

"Inner margin of the eyes accurately sinuate behind the middle. The antennæ are long and slender. The body is comparatively long and slender. The pronotum glabrous shiny."

Tenagogonus hyalinus Fabr. 1803.

Fabricuis, Syst. Rhyng., p. 258, 1803.

The following description is copied from Champion, Biol. Centr. Am. Heter. II, p. 153:

"Winged form. Rather robust, the head and pronotum shining, black, the head with two longitudinal lines, united posteriorly, and the sides behind, ochraceous; the pronotum with the lateral and posterior margins narrowly, two short lines on the anterior lobe, and a narrow median line

extending thence to the apex, flavous or ochraceous; the elytra blackish-brown, streaked with paler brown on their inner half; the body beneath and the pleura ochraceous, the pleura streaked with black; the venter also with a black line on each side; the antennæ blackish, with the basal half brown; the rostrum ochraceous, black at the tip; the legs brownish, the anterior femora paler towards the base; above thickly clothed with very short, fine, brownish pubescence, modifying the ground-color; the under surface and the pale streak between the black stripes on the pleura thickly clothed with silvery pubescence. Antennæ about reaching the hind coxæ, slender, joint 1 slightly stouter, 1 and 3 subequal in length, 2 a little shorter than 1, 3 shorter than 2. Pronotum not carinate, with the posterior margin thickened, the short anterior lobe distinctly defined. Elytra with thickened and very prominent nervures. Mesopleura strongly dilated before the intermediate coxæ. Mesosternum canaliculate anteriorly. Anterior femora and tibiæ slightly curved and rather stout in both sexes. Anterior tarsi with joint 1 very much shorter than 2. Posterior legs with the femora about one-fourth longer than the tibia and tarsus united, the first tarsal joint twice as long as the second.

"Male: Sixth connexival segment pointed at the outer apical angle; sixth ventral segment simply arcuate-emarginate; first genital segment acutely produced at the middle of the apical margin beneath.

"Female: Sixth connexival segment acutely produced at the outer apical angle, nearly reaching the tip of the last genital segment.

"Length, 8½ to 10; breadth, 2½ to 3$\frac{1}{10}$ mm."

Locality: Florida.

Tenagogonus franciscanus Stal. 1859.

Stal.-Freg. Eugen. Resa. Ins., p. 265, 1859.

Tenagogonus hesione Kirk. 1902.

Kirkaldy, Entomologist, XXXV, p. 137.

"Distinguished from the other American species of *Limnogonus* by much smaller size and proportionately greater width.

"Black, base of head medianly, a round spot near anterior margin of pronotum medianly, lateral margins of pronotum, ferruginous; antennæ, intermediate and posterior legs ferruginous, more or less fumate, anterior femora blackish, basally pallid. Elytra olivaceous, fumate, nervures blackish. Beneath covered with silvery grey pubescence. Head (with eyes) two-fifths wider than long, pronotum roundly angulate posteriorly.

"Male: Anterior tibiæ curved. Long. (to apex abd.), 5½ mm.

"America: Florida; Darien (collns. Montandon and Kirkaldy)."

Ohio added by Van Duzee's catalogue.

Genus METROBATES Uhl.

"Robust and broad. Winged form: head very convex, a little slanting forwards, between the eyes narrower than long, much narrower than the pronotum; eyes very large, viewed from above placed obliquely, subglobose, moderately prominent, their upper surface below the line of the vertex, projecting widely over the sides of the pronotum; with one or two impressed lines running across near the middle. Antennæ stout, almost as long as the entire body, the basal joint nearly as long as the three others conjoined, curved at base, and narrowing in that direction, much stouter in the male, and a little expanded at tip, the under side with erect hairs; second joint about one-third the length of the basal one, greatly enlarged at tip; the third shortest, enlarged at tip; fourth very stout, fusiform, almost as long as the second. Rostrum stout, hairy, extending beyond the basal line of the prosternum. Pronotum ample (in the unwinged form narrow and short, with the mesothorax forming the

largest division of the body), a very little wider than long, the posterior lobe large and extending back in the form of a broad triangle, with the sides nearly straight and the tip a little rounded; lateral margins (including the humeri) constituting high, broad ridges. Anterior lobe much narrower than the head across the eyes, the lateral margins and submargins lobately elevated. Anterior legs stout, the tibiæ a little curved at tip, with the process small and almost in contact with the surface on which it is situated; basal joint of tarsi about one-fourth the length of the second, the second carrying the unguiculi about one-third of its length from the tip. Intermediate femora about two-thirds the length of the posterior; the tibia not quite as long as the posterior femur and tibia conjoined, but equal in length to the distance from the base of head to the tip of the intermediate femur; tarsus equal in length to the posterior tibia and tarsus conjoined; hemelytra not covering the whole width of mesothorax, but much longer than the body; corium short, having two elongated cells occupying nearly the whole width; the nervures very prominent, membrane more than twice as long as the corium, having a submarginal nervure running around the entire circumference, following equally the curve of the tip, a longitudinal suture extends along the middle quite to the tip. Abdomen broad and short; the penultimate ventral segment of the female concavely curved on the posterior margin."

Metrobates hesperius Uhl. 1878.

Uhl., Proc. Boston Soc. Nat. Hist., vol. XIX, part IV, p. 1438.

"Opaque, velvety blue-black, or brown-black, densely pubescent, robust, the mesothorax very large and composing the larger part of the body. Head convex, robust, brown, at base rufous, or orange, the anterior part of which is invaded by a rounded spot of the black surface extending from the face; minutely, densely pubescent; rostrum black, shining beneath, densely grayish pubescent above, more or less orange at base. Antennæ black, pubescent, the basal fourth of the first joint orange. Pronotum very small in the unwinged specimens, less than one-half as long as wide, having the anterior margin a little concave; the surface closely, finely pubescent, the anterior lobe with a yellow, depressed spot on the middle, covered by a more or less wide gray, or lead-blue middle line, which color expands and covers the whole width of the tergum to its tip, omitting only a few black streaks on the disks and margins of the segments. The whole breast, venter, and two spots on the pleura lead color, with a sericeous gloss.

"The winged form has the pronotum blackish brown, densely pubescent, the middle of the anterior lobe broadly depressed, covered by an orange spot, lacking the bluish stripe. Coxæ yellow beneath, legs brownish black, the anterior pair yellow at base, and on the under side the yellow is a little farther extended. Sternum blackish, each side of it yellowish. Hemelytra dark brown, with a faint paler streak on the medial suture, the base and costal margin pubescent. Venter cinereous, the disk of the penultimate and base of the last segment yellow.

"Length to tip of hemelytra, 5 mm.; extreme width of mesothorax, 2 mm.; unwinged—length, 3 to 4 mm.; width of mesothorax, 1¾ to 2¼ mm."

Reported for Ontario, Maine, Massachusetts, Rhode Island, New York, Maryland, North Carolina and South Carolina, according to Van Duzee.

Genus TREPOBATES Uhler.

"As the name of this genus is preoccupied, and the genus has not yet been fully described, for lack of winged specimens, it becomes necessary to give the following characters, which are in augmentation of those given by Dr. Buchanan-White: Anterior tarsi normally three-jointed (exceptionally two-jointed); the hemelytra curved and tapering at base,

gradually becoming wider towards the tip, at which point it is a little triangular and rounded; the corium subtriangular and about one-half as long as the membrane, with three stout longitudinal veins, of which the costal is more bristly towards the base; the membrane has a pale longitudinal suture throughout, with a thick vein on the middle which does not quite reach the end of the loop that is formed by the two veins which run parallel to the margins and which converge on the tip; no transverse veins as in *Brachymetra.* In some specimens the acute tip of the scutellum projects from between the metanotal plates, in others it is atrophied. In two specimens the basal joint of tarsi was present on one side, and not on the other."—*Uhler.*

Trepobates pictus H. S.

Herrick Scharffer, Wanz. Ms., VIII, p. 111; Uhler, Stand. Nat. Hist., II, p. 270.

"It is of a yellow color, with a black stripe on the head, which is either interrupted or runs down to near the base of the rostrum; the rostrum is piceous, interrupted by yellow near the base; on the prothorax two black lines along the middle spread apart behind; a similar line occupies each side, and is continued unevenly back to the end of the mesothorax; on the latter a line runs down the middle with a dot on each side; and exterior to these the lateral, wider lines run backward and curve inwardly until nearly meeting on the middle of the posterior margin. Most of the sutures on the abdomen, pectus, and flanks are black, and black lines extend along the sides of all the legs. Many varieties occur in which the black color invades more or less of the surface, particularly of the upper side, so that some appear black, marked with a few yellow stripes and spots.

"In the unwinged state, although capable of laying eggs and continuing the species, these insects fail to acquire their full plan of structure, and there is consequently an arrest in the formation of the thorax. In this complete form the wing covers are elongate-obvate, smoke-brown; the coriaceous part rather less than half as long as the membrane, narrowly tapering towards the base, furnished with three stout veins, the outer and inner of which run nearly parallel to the margin, while the third extends along the middle, and ends in a small cell; the boundary between the two portions is made by a coarse transverse vein, and the base of the costal margin is quite pubescent. The membrane has the outer and inner submarginal veins of the corium continued through it to the tip, where the two unite in a loop; the middle one is continued to the very tip, in the form of a suture, and is paler than the adjoining surface. The wings are also brown, opaque, much shorter and narrower, than the wing-covers, with three long veins reaching to the tip, and a basal one curving towards the hind margin. Here, also, the pronotum occupies the whole width of the dorsum, lacks the suture which divides it from the mesothorax, and the two united are free, forming a cap over the other segments of the mesothorax, and behind them two transverse callosities, possibly the dorsal pieces of the metathorax, spread across the base of the wide first abdominal segment."

Localities: Kansas, Maine, Massachusetts, New York, New Hampshire, Rhode Island, New Jersey, Pennsylvania, Maryland, Virginia, North Carolina, Florida, Louisiana, Ohio, Illinois, Tennessee, and Arizona.

Genus RHEUMATOBATES Bergr.

Body comparatively short and broad, eyes convexly rounded interiorly. Fourth segment of antennæ never more than equal to third; basal segment of anterior tarsi much shorter than second; hind femur equal to or much shorter than the hind tibia and tarsus together.

KEY TO RHEUMATOBATES.

Taken from Bueno's Gerrids of Atlantic States.*

A. Hind femora and coxæ of male curiously swollen and distorted. Female with mesosternum unicolorous. *R. rileyi* Bergr.

AA. Hind femora and coxæ of male not swollen and distorted. Female with mesosternum yellow with the anterior margin and the two posterior diverging bands brownish-black, these bands not reaching to the posterior margin and dilated near the anterior margin. *R. tenuipes* Meinert.

Genus HALOBATES Eschs.

"Head triangular; eyes, globular; beak, short and stout. Fourth segment of antennæ longer than the third. Mesothorax very large; abdomen, short and conical; front legs, short and femora thickened somewhat. Middle legs, very long and slender. The hind legs shorter than the middle ones. Found upon the floating mats of seaweed often far at sea. The two species reported from our land were described by Eschscholtz in 1822. The descriptions here given are from Burmeister's Handbuch."

Halobates sericeus Eschs.

Eschscholtz, Entomographien, p. 108, 1822; Burmeister, Handb. d. Ent. II, p. 209, 1835.

"Corpore ovali, subtus argenteo, supra albo-cinereo; oculis flavis. Long., 1⅓‴."

Locality: Florida.

Halobates micans Eschs.

Eschscholtz, Entomographien, p. 107, 1822; Burmeister, Handb. d. Ent. II, p. 208, 1835.

"Corpore conico, subtus argenteo, supra cinereo, æneo, miconte; oculis atris. Long., 1⅔‴."

Locality: California.

B. Biology of the Gerridæ.

General Notes. The water striders are to be noted everywhere. Bueno says "their haunts range from living springs, clear, secluded, shady, and cool, to the vast expanse of the tropic ocean steaming under a torrid sun, or dashed by wild storms into mighty waves." So far as we know them, the fresh water forms place their elongate white eggs upon supports at the water's surface. They feed upon organisms nurtured in the water, or upon plants about the shore. They also prey upon floundering insects that chance to tumble into the water. Bueno and Drake have given us life history notes upon the group and Essenberg has studied the behavior of some of them.

Genus GERRIS Fabr.

For this country we have life history notes by Bueno upon *G. marginatus* and *G. remigis,* and by Drake upon *G. conformis.* The writer has studied the first two in Kansas.

Gerris remigis Say.

Habitat. This large strider is usually apterous and more often found on running water, or pools connected therewith, than on isolated small ponds. They are gregarious fellows, seeking a resting place in the shade of overhanging bank or bush, but taking wildly to the open when alarmed.

* A third species *R. trulliger,* Bergr. is described in Bul. Brookl. Ent. Soc. X, p. 63, 1915. My manuscript for this genus has been misplaced. Bergroth has a splendid paper in Ohio Naturalist, vol. VIII, p. 381.

Hibernation. De Geer, 1778, said of *Gerris lacustris* ". . . qu'il la gange pour se garantir contre le froid." Our large *G. remigis* winters as an adult hidden under some brush, logs or other shelter about the water.

Mating. De Geer also described the mating of *Gerris.* It begins in early spring and continues through the season.

Oviposition Dufour described the eggs of *Gerris* and their deposition. They are laid on supports projecting from the water, and upon floating objects as a rule beneath the water line. They are fastened by means of water-proof glue.

Incubation period. The writer finds it to be about two weeks for this species.

Hatching. These bugs split the egg shell longitudinally and upon hatching cast an embryonic molt which bears a shiny black "egg burster." This lies on the cephalic end between the eyes. It is figured on Plate XV. It has not ben noted heretofore by our American workers. Brocher has mentioned it for the European form. This very transparent, flimsy, delicate molt serves but the one purpose, that of aiding the bug to emerge. Bueno describes it as "a diaphanous pellicle, very soft and hairy, so soft that it does not retain its shape at all and is nearly invisible on the surface of the water." Bueno considers it in the nature of an amnion. It shows the 1-segmented tarsi, subapical claws, tibial combs on all the legs. In case the bug hatches under water it swims about until it can attain the surface.

Behavior. The new bugs resemble little spiders and jump about with the greatest alacrity.

Number of Instars. There are five instars. Each instar lasts about a week.

Food Habits. Predaceous upon insects, such as midges, and Notonectid nymphs, coming to the surface from below, and Jassids or other insects cast upon the water. About a drying pond they were feeding upon snails left stranded upon the ooze. It sometimes required maneuvering to pry the snail free from its support.

Dr. C. F. Curtis Riley of Syracuse University gives splendid notes on behavior. See Am. Nat., October to December, 1919.

DESCRIPTION OF STAGES.

The Egg.

Shape "Long cylindrical, rounded at both ends and slightly concave at micropylar end. There is one micropyle and the chorion is somewhat thickened at this end."—*Bueno.*

Color. White when first deposited, becoming amber as red eye spots appear.

Beuno has so recently published in an available periodical the descriptions of the instars that they are not reproduced here. (See *Ent. News,* May, 1917.)

Gerris orba Stal.

This species has been the subject of behavior studies by Essenberg.

Gerris conformis Uhl.

Habitat. Bueno said he had only found it on flowing waters, but Drake says it is a lacustrine as well as a fluviatile species. To the latter we owe the following notes:

Hibernation. As an adult.

Mating. In early spring.

Oviposition. Eggs are deposited on material just beneath surface of the water, fastened there with viscous substance which is waterproof.

Incubation. Eleven days.

Maturity. One adult came from the egg in 34 days. (See Ohio Nat. Vol. XV, No. 7, p. 501, May, 1915.)

Gerris marginatus Say.

The writer reared this in the summer of 1916. The following summer Mr. Bueno presented in *Ent. News*, 1917, a study on this insect. This is our common small Gerris, and is usually winged.

Habitat. On quiet pools and ponds as well as brooks and streams.

Hibernation. As an adult.

Mating. As figured on Plate XV. May last from a few minutes to many hours, during which time the female rows over the surface and darts here and there in pursuit of prey as though unincumbered.

Oviposition. The eggs are laid as in *G. remigis.*

Number of Instars. Five instars, each requiring from 3 days to a week.

Food Habits. Similar to *G. remigis.*

DESCRIPTION OF STAGES.

The Egg.

Size. Length, 3 mm.; diameter, 1 mm.

Shape. Elongate cylindrical.

Color. White when first laid, changing to dark color before hatching.

The Instars.

Described in July number of *Ent. News*, 1917.

Gerris canaliculatus Say.

Habitat. Bueno tells us this species likes secluded little coves and bays in ponds.

Number of Instars. Bueno says there are five; that he reared thirty individuals from one apterous female, and every one was macropterous.

Genus TENOGOGONUS Stal.

Tenogogonus hesione Kirk.

Drake has given us what we know about this species.

Habitat. A lacustrine species, mostly apterous, active and congregating in immense numbers near the shore in sheltered places.

Hibernation. "As ova and no adults could be found in early spring, the winter is probably spent as an egg."

Mating. Found mating in October. "Many of the pairs remained almost constantly 'in coitu' for several days."

Number of Instars. Five (?). Takes about 50 days from hatching to adult.

Food Habits. Eat small insects that fall into the water. Do not disdain food that has been dead some time.

DESCRIPTION OF STAGES.

The Egg.

Three times as long as wide; dirty greenish yellow in color.

Genus METROBATES.

Metrobates hesperius.

Habitat. This bug is lacustrine. Bueno says it "may be seen congregated in large patches of blackness on the smooth waters of our lakes or perhaps in the wide reaches of slow moving streams. Little else is known about this insect.

Genus TREPOBATES.

Trepobates pictus.

Habitat. This is a beautiful species, as its name would indicate. It is wide spread, and quite usually apterous. Here in Kansas, however, it frequents our ponds and is quite largely winged as taken in the spring.

Hibernation. From the collecting it would be assumed it winters as an adult.

Oviposition. The writer shows some figures of the egg masses of this species. They are laid in solid masses of gelatinous material on the under side of leaves and sticks in the water. The writer has found them under the leaves of Duckmeat and grass blades. The eggs are placed side by side and imbedded in a pad or matrix of yellowish white gelatin. There are from 3 to 10 eggs in a mass. (See plate XII.)

Incubation. From eggs laid in the laboratory June 19, young nymphs appeared June 24, a period of 5 days.

Hatching. Before hatching the eggs became beautifully marked with red spots, the large eye spots and sixteen other small dots, distributed as shown in the drawing on plate XV. These spots are located in various places on the nymphs, such as antennæ and joints of the limbs. The postnatal molt bears a black shiny "egg burster" like the Gerris. After hatching the nymphs swim about in the water by means of middle legs. They stand several hours of submergence at this time.

Food Habits. Source of food much as for their larger relatives.

DESCRIPTION OF STAGES.

The Egg.

Size. .99 mm. long; .312 mm. wide.

Shape. Elongate oval; anterior end more pointed.

Color. White, turning to amber; marked with red spots before hatching. (See pl. XV, fig. 13.)

First Instar.

Size. Length of body, .676 mm.; width, .364 mm.; width of head, .338 mm.; length of middle limb, 1.43 mm.; hind limb, 1.04 mm.

Shape. Remarkably like that of Gerris. Head, thorax and abdomen closely joined. The indentation between the prothorax and mesothorax being more marked than that between the head and prothorax. The sides of the body parallel and the abdomen extremely short. Tip scarcely reaching distal end of posterior coxæ.

Color. Yellowish brown, a light Y-shaped line is present upon the head, the stem of which passes posteriorly across the prothorax and widens to a broader band covering the median line of the long mesothorax which is met posteriorly by converging lateral bands of the same color. Eyes dark red, some pink spots show in the 1st, 2nd, and base of the 4th segments of antennæ. These are now almost obscured, but doubtless gave the pink color spots to the embryo within the egg shell. Limbs are smoky testaceous, but fairly light, as on the venter of the bug. The tip of the beak and the suture lines in front of the mesocoxæ being dark.

Genus RHEUMATOBATES Bergr.

Rheumatobates rileyi.

Habitat. There are three species of this peculiar group of little bugs. They live on quiet waters. In Kansas *R. rileyi* is common enough on the muddiest ponds and pools. The male of this species is of most bizarre shape. (See plate XVI.) Note the clasping antennæ and the strange twist to the hind femora.

Oviposition. Three summers have failed to disclose the nature of the oviposition. The ovipositor suggests that the eggs are hidden in the tissue of a plant. The writer figures this on plate XVI.

Food Habits. They feed upon insects dropped upon the water, and if watched in a pool teeming with ostracods they can be seen to scoop them out of the water and carry them about on the upturned tip of the beak.

Behavior. These insects are gregarious and very easily disturbed.

DESCRIPTION OF STAGES.

The Ovum.

Size. Length, .728 mm.; width, .208 mm.

Shape. Elongate cylindrical; one end bluntly pointed; the other end rounded and bearing a short projecting micropyle.

Genus HALOBATES Eschs.

Two species, *H. micans*, off the coast of Florida and *H. sericeus* off the coast of California. Little is known about these insects. Eggs found on a floating feather by the Vitor Pisani expedition appeared from the embryo within to be eggs of Halobates. Other females taken have been figured with eggs extruded and clinging to the abdomen. Their food must be the minute Crustacea of the water, for they range far from land and are taken on coast only when driven there by storms.

Lundbeck, 1914, in a most interesting paper, deals with the oviposition of these bugs.

He studied the Steenstrup material. He gives a photograph of the tail of a bird, the Noddy (*Anous stolidus*), showing many eggs of Halobates on the feathers. He confirms Witlaczel's observation that the embryos have the long middle and hind legs bending around the end of the abdomen, and then along the dorsal side up towards the head. He gives a summary that is quoted below:

"The eggs of the Halobates are comparatively large, about 1 mm. long, elongated oval or cylindric with rounded ends. The ventral side is arched, the dorsal side flat or slightly arched, the front end somewhat broader than the posterior end. The color varies gradually from yellowish-white to red, as the development advances. Chorion is solid, thicker or thinner; it is simple, without sculpture, or with a more or less strongly marked sculpture after the species. The sculpture is most strongly marked on the ventral side and the anterior end, and decreases towards the dorsal side, where it almost or wholly disappears. Only one micropyle, situated in or very near to the front pole; it forms a canal, issuing from a funnel-shaped deepening in the surface; the canal runs somewhat tangentially in the chorion, and is rectangularly bent. The female can bear a few eggs at end of abdomen, but probably only for a rather short time. The egg-laying takes place on all objects possible floating on the surface of the sea. One female produces about 25 eggs. In general, several or many females lay their eggs on the same object. It seems as if the eggs can also be laid without being attached to any under layer, so that they form a floating heap. The eggs are apparently laid without definite order, or this is at any rate only very insignificant; this seems, however, partly caused by the circumstances that many females lay their eggs together; when groups of eggs that may be supposed to proceed from one female are examined, there often appears some arrangement in a few transverse rows, following each other, and consisting of parallel eggs, all with their front ends in the same direction. The eggs are always deposited with the dorsal side against the substratum, the ventral side upwards; they are fastened with a mass which in general entirely envelops them, and which no doubt is gelatinous. The opening of the egg shell occurs through its splitting in the front end, down the middle of the dorsal and ventral side, to a little beyond the middle, so that two lateral valves are formed. The larvæ probably moult very soon after their escape from the shell."

Family VELIIDÆ Am & Serv. 1843.

A. Taxonomy of Veliidæ.

Family Characteristics. Surface dwellers which are usually plump bodied, and broadest at the shoulders. The antennæ are 4-segmented, and the head is shorter than the thorax, including the scutellum. The middle legs are placed about equidistant from front and hind pairs (except in Rhagovelia). The hind femora do not extend much beyond the apex of the abdomen. The ocelli are obselete or absent. Beak 3-segmented; tarsi 1- or 2-segmented in front, and 2- or 3-segmented in the others. Most of these bugs are small. We have, according to Van Duzee, 4 genera, *Microvelia, Macrovelia, Rhagovelia* and *Velia,* with 9 species, 1 species, 4 species and 4 species respectively.

KEY TO GENERA.

A. Last antennal segment longest.
  B. Ocelli in contact with inner margin of the eyes. *Macrovelia.*
  BB. Ocelli absent. *Microvelia.*

AA. First antennal segment longest.
  B. Third segment of middle tarsus split and with feathery hairs set in the silt. *Rhagovelia.*
  BB. Intermediate tarsi not split. *Velia.*

Genus MICROVELIA Westw. 1834.

Westwood, Ann. Soc. Ent. Fr., III, p. 647.

"All the members of this genus are small, compact bugs. Both winged and wingless forms occur. The legs are rather short and stout. The fore tarsi are 2-segmented, the two hind pairs 1-segmented. The eyes are hemispherical, placed next to the pronotum. Ocelli are absent. The hemelytra when present are as long as the abdomen, and have six consecutive areoles, of which the basal are smaller than the others, while the apical ones emit two nerves."—*Uhler.*

Eight species listed for our range. Two of these are described in a periodical not available to the writer. A key for 6 species is possible. Bueno gives us a key to five species. (See Bulletin Brook. Ent. Soc., XI, p. 52.) Bueno has promised a monograph on this genus.

BUENO'S KEY TO THE EASTERN MICROVELIA.

In Bull. Brookl. Ent. Soc.

The species *M. signata* Uhl., *M. marginata* Uhl., and *M. robusta* were not placed in the key because they were not in the range treated.

A. Antennæ comparatively short and stout, not exceeding length of head and thorax taken together; legs short and stout. *M. atrato* Bueno.

AA. Antennæ slender of varying lengths.
  B. Posterior tibiæ curved in male, straight in female; antennæ short, not as long as head and thorax taken together; apterous male, long, slender, fusiform, female, short, broad, nearly orbiculate. *M. borealis* Bueno.
  BB. Posterior tibiæ straight in both sexes.
    C. Posterior tarsi 3-segmented.
      D. Antennal segment 3 longer than 1, 4 subequal to 2 and 3 taken together; segments 3 and 4 slender, equally stout and of the same diameter throughout, 4 tapering at the end, antennæ very long; hemelytra much marked with white. *M. albonotata* Champ.
      DD. Antennal segment 3 subequal to 1, 4 shorter than 2 and 3 taken together, stouter than 3, fusiform; apterous form with dorsal patches of blue gray pile. *M. fontinalis* Bueno.
    CC. Posterior tarsi 2-segmented; antennal segments 1 and 3 subequal, 4 much shorter than 2 and 3 taken together; apterous form with dorsal patches of silvery white pile; winged form with unicolorous hemelytra. *M. americana* Uhl.

Microvelia atrata Bueno. 1916.

Bueno, Bul. Brookl. Ento. Soc., XI, p. 60.

"Head comparatively short and broad; eyes round, rather prominent; antennæ short, rather stout, not much longer than head and thorax taken together, joint 1 stoutest, 3 thinnest, 2 shortest, 4 longest, fusiform, 3 shorter than 4 and subequal to 1, which is longer than 2. Pronotum not much produced, rounded behind; humeri prominent. Collum yellowish with narrow black median line; suture before middle of thorax grayish pilose. Hemelytra not so wide as abdomen. Corium and clavus milk-white at base, a white patch in the middle cell. Legs comparatively short and stout, tibiæ straight in both sexes. Subparallel in shape.

"General color, sooty black; pronotum narrowly flavous toward apex; connexivum flavous edged with black above and below; grayish black pilose beneath; femora light yellow basally.

"Long., 2 mm.; lat., .9 mm. at humeri.

"Type, female, Billy's Island, Okefenokee Swamp, Georgia, June, 1912, collected by J. C. Bradley.

"Allotype, male, differs from female in having the genital segment rounded and slightly prominent. Same locality and date.

"Long., 1.7 mm.; lat., .8 mm. at humeri.

"Apterous male, subparallel in form; genital segment visible from above, small, not very prominent; a glabrous indentation in the last abdominal segment; connexivum not much reflexed; prothorax short with two more or less obscure transverse sutures. Vestigial wings visible at posterior edge of thorax as two minute milk-white pads. Entire insect brown pilose.

"Long., 1.6 mm.; lat., .8 mm. at widest part.

"Morphoparatype, apterous male from same locality, same date.

"Apterous female, differs from male in form, which is obovate, and in the shape of the genital segment, which is visible from above.

"Long., 1.8 mm.; lat., .9 mm. at widest part of abdomen.

"Paratype, same locality and date as type.

"Additional paratypes, four specimens of the forms.

"This velvety black species secured in numbers by J. C. Bradley, and so far is known only thence."

Locality: Georgia.

Microvelia borealis Bueno 1916.

Bueno, Bul. Brookl. Ento. Soc., XI, p. 59.

"Head with an impressed line down the middle; antennæ slender; not quite as long as head and thorax taken together; joint 1 stoutest, 3 slenderest, 2 and 4 nearly equal in thickness, the last fusiform; joint 2 shorter than 1, which is subequal to 3 and shorter than 4, the longest; a white line next the eyes. Pronotum as long as broad, with a distinct collum, rounded behind, humeral angles prominent, tumid. Both head and thorax velvety black, except for the silvery stripe next the eyes in the former. Eyes round, diameter half the distance between them. Hemelytra as wide as abdomen, entirely membranous; nervures prominent, black, cells gray, except apical, which is white. Femora slightly stouter than the tibiæ, legs pilose, posterior tibiæ curved, bases of femora lighter in color. Genital segment prominent. Fusiform in shape.

"Long., 1.6 mm.; lat., .7 mm., at humeri.

"Type, winged male, taken at Cranford, N. J., on the Rahway river, August 8, 1904.

"Winged female: Differs from the male principally in the broader form, sides of abdomen subparallel and more or less curving; hemelytra do not quite cover connexivum; posterior tibiæ straight.

"Long., 2 mm.; lat., .8 mm.

"Allotype, winged female, Staten Island, N. Y., August 19, 1905.

"Apterous male: Fusiform, pronotum tumid, divided by distinct sutures into three segments; mesonotum with a deep suture behind middle, directed anteriorly at each end; genital segment prominent; abdominal segments subequal. Velvety gray black in color.

"Long., 1.9 mm.; lat., .7 mm.

"Morphotype: Apterous male, from Staten Island, same date.

"Apterous female: Orbiculate, genital segment truncate; gray and black coloring, much more marked and definite than in male.

"Long., 1.6 mm.; lat., 1.1 mm. at widest part.

"Morphoparatype: Apterous female, Staten Island, N. Y., June 3, 1905. Nine other paratypes of both sexes and forms from Westfield, N. J., Yaphank, L. I., and Staten Island.

"In all the underside of the head, pro- and mesosternum are yellowish, as well as the coxæ, trochanters and greater part of femora."

Localities: New York, New Jersey, Kansas, Maine and Massachusetts.

Microvelia albonotata Champ. 1898.

Champion, Biol. Centr. Am. Heter., vol. II, p. 129.

"Winged form. Male moderately elongate, narrow; black, a narrow transverse line in front of the pronotum, and also the lateral margins beneath, the rostrum, trochanters, and coxæ, and the connexival margins, flavous; the head with two posteriorly coalescent stripes between the eyes, and the pronotum with an evanescent median line anteriorly, rufofulvous; the elytra brown, with two long oblique streaks extending from the base downwards, a long streak beyond these, a rounded spot near the cost beyond the middle, and an oval spot at the apex, silvery-white; the antennæ brown, paler at the base; the legs brownish, with the femora indeterminately flavous at the base; the body very finely and sparsely pubescent, the costal margins of the elytra ciliate towards the base, the under surface with a bluish-gray pruinosity; the antennæ and legs pubescent, the antennæ also with some longer hairs. Antennæ very slender, not nearly so long as the body, joint 1 rather more than one-half longer than 2, 2 short, 3 about twice as long as 2, very slender, 4 much longer than 3. Pronotum rounded at the apex behind, with indications of a faint mediam ridge. Elytra with rather feeble nervures. Legs very slender, moderately long.

"Length, 2¼ mm.; breadth, ⅞ mm."

Bueno, in his Veliinæ of Atlantic States, adds:

"Apterous form: Connexivum strongly reflexed, with brown patch on each segment; dorsum black, except three last abdominal segments, which are broadly greenish, the last entirely so. Genital segment large, prominent. Thorax tumid, mesothorax rounded behind; metathorax straight, form narrow, abdomen subparallel. Male, Morphotype, male, Fort Lee District, N. J., October 10, 1903.

"Apterous female: Differs from the male in having the abdomen posteriorly roundedly truncate; form obovate. The specimen in question has the dorsum nearly entirely a deep velvety black; another specimen shows but little black. Morphoparatypes, 2 females, Fort Lee District, N. J., October 10, 1903; Fly Creek, N. Y., August 29, 1906.

"In this species, as in the other, the most obvious character is in the long, thin antennæ. It cannot be mistaken for any other species, being the largest of our eastern forms, except americana, from which its slim body, long thin antennæ and white-spangled hemelytra at once distinguish it. The apterous are more glabrous and much less velvety in appearance than the winged."

Localities: New York, New Jersey, Maryland, Florida and Illinois.

Microvelia frontinalis Bueno.

Bueno, Bul. Brookl. Ent. Soc., XI, p. 58, 1916.

"Apterous form: Head nearly as broad as long; white pile next to eyes. Eyes round, small, prominent, black; ocelli close to eyes.

"Antennæ nearly half as long as the entire insect; joints 1 and 2 subequal, 1 shortest, 3 longer than 2, 4 longest; joint 1 stoutest, 2 following, 3 slender and 4 stouter than 3, fusiform; all joints more or less pilose, especially 4.

"Thorax longer than first three dorsal abdominal segments. Femora in all three pairs of legs stouter than tibiæ, hairy, all tibiæ straight. Femora flavous toward base, tibiæ entirely fuscous.

"Six abdominal dorsal segments visible, first and second dorsally with lateral patches of fine blue-gray pile; five and six with a median large patch, nearly covering the entire segment; all segments margined with black; first four segments brown above; all segments a lighter brown on the underside, covered with a sericeous pile. Connexivum strongly reflexed in both sexes, more so in the female; spiracles visible at connexivum; male genital segment not very prominent. Genital color fuscous, strongly pilose.

"Type, female taken at White Plains, Westchester county, N. Y., June 30, 1912; paratypes, four specimens same place, same date, two Westfield, N. J., September 3, 1904.

"Long., 2.3 mm.; lat., 1.1 mm. at widest part.

"Only the wingless form is known. It was taken in numbers in a spring in a marshy woodland, where it clings to the long mosses growing into the water or walks about leisurely a short distance from the rocky side of the basin. The blue-gray patches of pubescence on the dorsum are distinguishing characteristics. The characters given distinguish it from *M. americana*, for small specimens of which it might be mistaken. In antennal structure it is near *M. albonotata*."

Localities: New York, New Jersey and Massachusetts.

Microvelia americana Uhler.

Uhler-Hemiptera of Colorado, Agri. Exp. Sta. Bull., 31, p. 61 (tech. ser.).

"Dark brown, velvety above, more or less powdered with plumbeous, body a little tapering behind the curved base of sides. Head short, triangular before the eyes, margined with silvery, prostrate pubescence from behind the eyes and along their inner border forward to the cheeks; the throat testaceous; middle line of head obsoletely callous-carinate; rostrum testaceous, piceous at base and tip, reaching to the posterior line of the anterior coxæ; antennæ slender, obscure testaceous, darker on the tip of the first and second joints, the second joint shortest, the third and fourth much more slender, the fourth a little longer than the third. Pronotum triangular both before and behind the humeral angles, the anterior division very slightly sinuated on the sides, feebly notched at the end of the scutellum behind the anterior lobe; collum distinct, with an orange band on the middle; the surface rugulose and punctate behind this; the lateral and posterior margin orange, the tip a little rounded; the humeral angles moderately subacute, with the edge a little callous. Pleural pieces bordered with rufo-testaceous; the coxæ, trochanters border of sternum, and legs yellowish-testaceous, with the femora, tibiæ and tarsi dusky or piceous above. Scutellum fuscous, almost completely concealed beneath the projecting pronotum. Hemelytra pale smoke-brown, narrower than the abdomen, with the veins darker, and a short streak at base of corium pale yellowish. Tergum rufous along the middle, blackish exterior to this: the connexivum both above and below, orange interrupted with black. The underside dull black with a tinge of plumbeous, a little sericeous, the posterior segments rufous on the middle, and the genital segment yellow.

"Length to tip of venter 3 mm. Width of pronotum, 1.25 mm. This is a common species in Maryland, and is also found in North Carolina. It has also been collected in Colorado, and in the vicinity of San Diego, Cal. In Maryland it occurs on the borders of small streams during summer, and is occasionally found full-winged in the month of June. The male is narrower and more wedge-shaped posteriorly than the female."

Localities: Ontario, Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, New York, New Jersey, Pennsylvania, Maryland, District of Columbia, Virginia, North Carolina, Florida, Kansas, Colorado, New Mexico and California.

Microvelia signata Uhl.

Uhler, Proc. Calif. Acad. Sci. Ser., 2, vol. 4, p. 288.

"This species has somewhat the form of *M. modesta* Uhler, but it is a longer and much more conspicuous insect; the color is a dark brown, with more or less bluish bloom, and minutely pubescent. Head short subconical, with a smooth grooved line on the middle; antennæ russet-brown, paler towards the tip, the joints long; rostrum dull testaceous, dark at tip, reaching behind the anterior coxæ. Pronotum moderately long, convex, feebly sinuated on the sides, the anterior submargin with a bright orange band which does not reach the sides; sternum and pleural segments dark plumbeous, bordered with testaceous. Legs pale testaceous, obscured above with fuscous and the tarsi more or less fuscous. Hemelytra velvety, long, and much narrower than the pronotum, clavus with a white streak, corium with a longer white streak at base which grows wider posteriorly, the membrane long, marked with one or two faint spots near base, with a clear long spot beyond and another longer near the tip. Venter dull yellow, brighter on the connexivum, and dusky along each side of disk.

"Length to tip of venter, 3 mm. Width of pronotum, 1⅓ mm.

"This beautiful little species was taken at San Esteban, in April, by Mr. Charles D. Haines."

Localities given in Van Duzee: California, Colorado and Mexico.

Microvelia robusta Uhl.

Uhler, Proc. Zoöl. Soc. London for 1894, p. 219.

"Shorter and comparatively more robust than *M. modesta.* Colors about the same, except that there is an absence of pale color from the venter and no yellow border on the connexivum. The head is immersed nearly up to the eyes in the pronotum; the eyes are bordered internally with prostrate white pubescence; the front of the pronotum is shorter and less contracted, densely covered with white pubescence, which is laid upon a faintly yellow band; the pleural pieces are not broadly bordered with testaceous, and the posterior femora are only a little longer than the middle ones; the last joint of antennæ more than one-third longer than the third joint. The hemelytra are smoke-brown, often pale, with two white diagonal streaks at base, pale spaces in the areoles, and a white pyriform spot in the apical areole; the costal area is almost linear, deflexed, pale, and marked with a row of remote brown dots.

"Length to tip of venter 2 mm.; width of pronotum ⅞ mm.

"A few specimens were collected at Woburn and Beaulieu, August 25, at an altitude of 700 feet above the sea, on the surface of a stagnant pond; another specimen was taken on the Mount Gay estate, in September. (St. Vincent.)"

Locality: Florida.

Microvelia Marginata Uhl.

Uhler, Proc. Zoöl. Soc. London, 1893, p. 719.

"Dull black, nearly wedge-shaped, minutely pubescent, and obsoletely punctate, with the breast orange and the pronotum bordered with orange. Head rather blunt, convex between the eyes, a little compressed and produced at the end of the clypeus, the underside pale testaceous. Antennæ stout, closely hairy, black; third and fourth joints longer than the others, the fourth longest, acutely tapering at tip; the basal joint thicker than the others, much longer than the second, pale beneath. Rostrum stout and swollen at base, reaching behind the anterior coxæ, pale testaceous, piceous at tip. Pronotum broad, moderately convex, with the humeral angles bluntly rounded, and not prominent as in *M capitata*, Guer. Pectus broadly yellow, dusky on the middle and posteriorly. Coxæ and legs pale testaceous; the posterior legs dusky above, and fulvous on the middle of the tibiæ. Scutellum dusky, mostly concealed by the pronotum. Wingcovers black, bluntly rounded at tip. Abdomen black above, tinged with lead-color and a little sericeous beneath, the lateral margins broadly fulvous; the venter has sometimes a row of fulvous dots each side.

"Length to tip of abdomen, 1¾ to 2 mm., to end of wing-covers, 2¼ mm.; width of pronotum, ¾ mm.

"Several specimens, both winged and unwinged, were collected by Mr. Smith in the pools of cool water at various localities on the island of St. Vincent."

Localities: New Jersey, Maryland, Florida and California.

Genus MACROVELIA Uhler 1872.

"General form of *Microvelia*, Westwood, but much more elongated. Head long and narrow, subconically narrowing toward the tip; the division before the eyes several times longer than that behind them; cranium arched, curving downward; the tylus short, forming a narrow, blunt carina at the anterior extremity. Antennæ slender, reaching beyond the tip of the scutellum; the basal joint stoutest, narrowed at base, a little curved; second a little shorter, stout, enlarged toward the tip; third and fourth very slender, subequal in length to the basal one. Eyes round, placed on the sides a little below the upper line of vertex and near the occiput. Ocelli in contact with the inner margin of the eyes. Rostrum very slender, reaching beyond the anterior coxæ; the basal joint very short, ring-like; the second joint very long, about three times as long as the apical one. Thorax subcylindrical, widened behind, bilobate by reason of a transverse constriction before the middle; the anterior lobe with a tumid callosity each side; collum distinctly defined; humeral angles knob-like, posterior margin of pronotum scutellum-like, the tip bluntly rounded. Hemelytra narrower than the abdomen; the corium narrow, and with the membrane occupying also its inner margin. Legs long and slender."

Macrovelia hornii Uhler 1872.

Uhler, Hayden's Surv. Terr. Rept. for 1871.

"Fulvous, or reddish-brown, finely pubescent; the cranium bounded each side against the eyes by an impressed, oblique line, on the inner margin of which is a blunt, faintly elevated, oblique carina; the middle line slender, fuscous; cheeks and gular surface blackish; the space behind the eyes transversely tumid, the ridge joining inward to the slender carina, which runs along the whole length and forms a substitute for the buccalæ. Eyes dark brown. Antennæ yellowish-testaceous; the ends of the joints darker, and the two apical joints a little infuscated. Pronotum bright fulvous, coarsely, remotely punctured with fuscous, each side of the middle of the anterior lobe and disk, with a feebly elevated,

longitudinal line; just behind the collum are two very slightly elevated, approximate tubercles; sides before the posterior lobe emarginated, the latero-posterior margins sinuated and the edge recurved. Pectus black, with the margins of the pleural segments fulvous. Legs pale yellow; the knees, tips, and a cloud upon the femora and the tarsi, dusky. Hemelytra in the fully winged, fuscous, silvery pubescent, with a large white spot at base, the costal margin and sometimes the inner margin of corium blackish; membrane paler near the tip. Connexivum pale, with a dark spot at the tip of each segment; venter pale fulvous, densely golden pubescent, the sides, superiorly, with a broad, blackish stripe not quite reaching to the tip. The short-winged form has the hemelytra dark brown, with a streak of white at base.

"Length, 4-5 mm.; width across the humeri, 1-1¼ mm.

"Obtained at Fort Defiance, New Mexico. The species is named after Dr. George H. Horn, to whom I am indebted for specimens from California and Arizona."

Genus RHAGOVELIA Mayr. 1865.

Broad shouldered bugs of fair to small size, characterized by the long deeply-split terminal segment of the tarsus of the middle leg.

KEY TO RHAGOVELIA.

A. Tarsi of front leg 3-segmented, other tarsi 2-segmented (apterous). Hind femora, not spinose. Lead or gray in color.
R. plumbea Uhl.

AA. Tarsi 3-segmented on all limbs.

B. Posterior femora moderately incrassate and spinous in both sexes. Venter depressed at the base in the male.
R. armata Burn.

BB. Posterior femora moderately incrassate in the male; more slender in the female.

C. Sixth ventral segment broadly flattened along the middle and feebly arcuate; emarginate at the apex.
R. distincta Champ.

CC. Sixth ventral segment not broadly flattened along the middle. Strongly arcuate, emarginate at the apex.
R. obesa Uhl.

Rhagovelia obesa Uhl.

Uhl., Proc. Boston Soc. Nat. Hist., vol. XIX, part IV, p. 434.

"Allied to *R. collaris* Mayr (Burm.), but differs in the colors, in the more contracted abdomen, with its acutely produced posterior tips of the connexivum, and in the absence of dense long hairs at the tip of venter in the same sex.

"Brownish, or bronze-black; the under side bluish, sericeous; when very mature less polished, but more densely powdered with bluish, or cinereous bloom. Head black, velvety, the front almost truncated, cinereous, with an impressed longitudinal line running almost to the base, a few long hairs about the sides and above; the cranium a little elevated on the middle, extending back in the form of a triangle; the base of the occiput transversely a little carinately elevated. Labrum and lateral lobes yellowish, or rufo-piceous; rostrum black, reaching to the tip of the anterior coxæ. Eyes round, brown. Antennæ black, excepting the base of the basal joint, less hairy than in *R. collaris;* the basal joint stoutest, curved, about twice as long as the second joint, the second sub-

equal to the third, the fourth decidedly shorter than the third. Thorax obese, the pronotum velvety blackish, sparingly clothed about the sides with fine golden pubescence; collum with an orange band which is interrupted in the middle; middle line faintly carinated; the tip of pronotum produced at tip, curved upwards, its extreme end expanded, emarginated, and each process granulated; the humeri prominent in the winged individuals, in the unwinged it is obliquely rounded. Pectus bluish, sericeous, each side of prosternum broadly orange. Coxæ, trochanters, and usually the base of femora, yellow; the femora bronzed or bluish-black, minutely hoary pubescent; the tibiæ and tarsi duller black; posterior femora of the males stouter than of the females, in both with a yellow, black-tipped, curved spur beyond the middle, and from it to near the tip series of minute teeth. Abdomen moderately compressed (very strongly compressed in the unwinged females), minutely sericeous, pubescent, excepting on the middle of tergum, which is bald, shining black; the raised upper edge of the connexivum orange, in the female its posterior tips produced into long slender spines. The middle of the antegenital ventral segment of the male quadrately, broadly flattened, each side of which a little elevated. Basal genital segment of the female broadly black on the middle. The cerci of the male are long, slender, curved, hairy processes. Length, 3½ to 4 mm. Breadth of pronotum, 1¾ mm."

Localities, taken from Van Duzee: Ontario, Maine, Massachusetts, Vermont, New York, New Jersey, Pennsylvania, Maryland, District of Columbia, Virginia, North Carolina, Florida, South Carolina, Ohio, Michigan, Tennessee, Utah, and California.

Rhagovelia distincta Champ.

Champion, Biol. Centr. Am., II, p. 135.

"Winged form. Moderately elongate, black, the legs with a green or bluish-green lustre, the pronotum with a narrow transverse fulvous mark on each side of the disc in front, the base of the antennæ, the prosternum, the coxæ and trochanters entirely or in part, the base of the anterior femora, the connexival margins, and in the males the terminal ventral segment in the middle and the underside of the first genital segment, more or less flavous; the pleura and under surface bluish-grey; the body, legs, and antennæ very finely pubescent, and also clothed (the two apical joints of the antennæ excepted) with long scattered setæ, the pronotum usually with a transverse patch of greyish or silvery pubescence on each side in front. Head with a smooth impressed median line; antennæ moderately long, joint 1 about one-half longer than 2, 2 and 3 equal in length, 4 shorter than 3, stout, fusiform. Pronotum with a distinct median ridge, and produced behind into a spiniform process, the surface sparsely and finely punctured. Legs long and rather slender, the hind tibiæ with a very short, indistinct tooth at the apex; intermediate tarsi with joints 2 and 3 subequal in length.

"Male. Anterior tibiæ dilated in their apical half; posterior femora moderately incrassate, armed on the inner side with a long, partly flavous, tooth at about one-third from the base, and with a row of short teeth extending thence to the apex (in some of the well-developed apterous examples also closely and finely denticulate along the basal third); posterior tibiæ finely denticulate and slightly sinuous within. Pronotal spine short. Sixth ventral segment broadly flattened along the middle and feebly arcuate-emarginate at the apex.

"Female. Posterior femora not stouter than the intermediate femora, armed with a very long, acute, blackish tooth at about the middle, and very finely denticulate thence to the apex; posterior tibiæ straight, ob-

soletely denticulate within. Pronotal spine very long, stout, and raised, armed with a strong tooth at the base beneath.

"Length, 5 mm.; breadth (of the pronotum) 1½ mm.

"Apterous form. Male and female. Fusiform, the pronotum abbreviated and rounded behind; the abdomen metallic green above, with a stripe of greyish pubescence running down each side of the dorsal surface; the connexivum very broad in the females, extending inwards and overlapping the dorsal surface of the abdomen, the two portions nearly or quite meeting along the median line.

"Var. Apterous form. Male and female. The anterior femora dark to the base; the coxæ and trochanters darker, the latter, at most, flavous at the base, the sixth ventral segment broadly flattened, the flattened portion limited on each side anteriorly by a short, angular, longitudinal ridge."

Found in Indiana.

Rhagovelia armata 1898.

Description taken from Champion Biol. Centr. Am. Heter.

"Winged form. Male. Moderately elongate, brownish-black, the legs with an æneous lustre, the base of the antennæ, a transverse band on the front of the pronotum, the prosternum, all the coxæ and trochanters, the basal half of the anterior femora, the hind femora at the base, within, and beneath, the connexivum, the last three ventral segments broadly in the middle, and the genital segments beneath, flavous or fulvous; the pleura and sides of the abdomen bluish-gray; the elytra blackish-brown, the nervures darker; the head and pronotum somewhat thickly clothed with short yellowish pubescence, the head and propleura with a few long bristly hairs; the costal margins of the elytra, the sides of the body, the legs, and antennæ pubescent, the two basal joints of the antennæ, the margins of the genital and sixth connexival segments, and the legs clothed also with long scattered setæ. Head with a smooth impressed median line; antennæ moderately elongate, joint 1 rather more than one-half longer than 2, 2 and 3 subequal, 4 a little shorter than 3, pointed at the tip. Pronotum produced behind into a long spiniform process, which is armed with a stout spine beneath. Legs moderately stout; anterior tibiæ dilated in their outer half, grooved beneath; posterior femora moderately incrassate, armed with a long tooth at the middle, and with a row of short teeth extending thence to the apex, these teeth diminishing in length outwards; posterior tibiæ slightly sinuate and finely denticulate within, straight on their outer edge, and with intermediate tarsi with joints 2 and 3 subequal in length. Ventral segments land 2 and the intercoxal portion of the metasternum depressed, the two segments with indications of a median ridge, the sixth ventral segment feebly emarginate at the apex and depressed along the middle behind.

"Apterous form. Female. Fusiform, the pronotum abbreviated and rounded behind; the posterior femora a little less incrassate, with the first (or median) tooth longer and those near the apex shorter; posterior tibiæ straight and finely denticulate on their inner edge.

"Length, 5¾ mm.; breadth (of the pronotum of the winged male), 2 mm."

Taken in Texas.

Rhagovelia plumbea Uhl.

Uhler, Proc. Zoöl. Soc., London, 1894, p. 217.

"Only the unwinged form is at present known. It is short and thick, subconical posteriorly, bluish plumbeous, opaque, minutely hairy, with the sides of the abdomen broadly reflexed. The head wide, convex, with a slender black line on the front, the orbits of the eyes bordered with yellow; the rostrum testaceous, reaching considerably behind the anterior

coxæ; antennæ moderately long, brownish, finely pubescent, the basal joint yellow at base, much longer than the third, which is also much longer than the second, the fourth about as long as the second, thick, distended in the middle. Pronotum very moderately convex behind the middle, sloping posteriorly; the anterior lobe short, collar-like, with oblique sides, a yellow spot on the middle, and feebly carinate lateral margins, it is separated from the posterior lobe by a deeply incised line; the posterior lobe is somewhat abruptly wider, with strongly reflexed lateral margins and subacute humeral angles, with the posterior margin abruptly deflexed; a broad segment behind this has in the depressed outer corner a tumid callosity which occupies the position of the wing-pad. The propleural flap is mostly yellow, as is the cap of the intermediate, and posterior coxæ and also coxæ, trochanters, base of anterior femora, and the immediate base of posterior femora; other parts of legs fuscous, sericeous pubescent, and the posterior femora unarmed. The posterior border of last ventral segment and sometimes the genital segment yellow.

"Length to end of abdomen, male, 2½; female, 3¼ mm. Width of pronotum, male, 1; female, 1¼ mm.

"This is a common species on the surface of salt water around the inlets of the Florida Keys. Several specimens were secured in the Bay of St. George's, on the leeward side of Grenada, September 6, on the surface of the sea. Only specimens taken *in copula* were kept.

"Others were captured at the southern end of the island of St. Vincent, May 24, swimming on the sea, in a sheltered and still place near the shore. Gregarious in habits, 50 to 60 together. They were also taken *in copula* at this time.

"The male is very much smaller than the female, and the latter is usually marked by a carinate line on the middle of the contact of the two lobes of the pronotum."

From Florida now, as well.

Genus VELIA Latr. 1804.

The largest bugs of the family belong here. The tarsi are 3-segmented all around, and the middle tarsi are not cleft. Dimorphism as to wings occurs. Ocelli are absent. Four species for our range.

KEY TO VELIA.

A. Intermediate tarsi much longer than the posterior tarsi; segment 2 much longer than 3; segment 2 of hind tarsi shorter than 3.
V. australis Bueno.

AA. Intermediate tarsi little longer (if any) than the posterior tarsi.
- B. Intermediate tarsi, with segments 2 and 3 subequal.
  V. stagnalis Bueno.
- BB. Intermediate tarsi, with segment 2 longer than 3.
  - C. Antennæ, with segment 1 one-half longer than 2; legs rather short; 5th ventral segment not produced in male.
    V. brachialis Stal.
  - CC. Antennæ, with segment 1 nearly twice as long as 2; legs long; 5th ventral segment produced in the male.
    V. annulipes Champ.

Velia australis Bueno.

Bueno, Bull. Brookl. Ento. Soc., vol. XI, p. 54.

"Head triangularly obtusely produced with a median impressed line; eyes, globose, a little less in diameter than the distance between them. Antennæ slender, first joint stoutest, longest, curved; second joint thinner than first, but stouter than third and fourth, shortest; third and fourth joints slender, of nearly equal thickness throughout, subequal in length; all pilose and setigerous.

"Thorax faintly carinate, roundedly produced posteriorly, deeply punctured; two transverse impressions before the middle, the posterior with four deep foveate punctures; lateral angles prominent.

"Hemelytra (or tegmina) narrower and slightly shorter than abdomen, with slight distinction of texture between corium and membrane.

"Femora stout, anterior shortest, intermediate longest; all the tibiæ are longer than the corresponding femora; intermediate tarsi longest, anterior shortest, first joint in all minute, second joint longest in second and third pair of tarsi, third joint in first pair.

"In the middle section of the metapeuræ is an obscure and scarcely distinguishable opening, protected by three long black upwardly curving spines, which can be seen from above. This is a distinguishing character of this species, as it is apparently not found in other American forms described and in the four or five known to me in nature.

"Color, brown; silvery pilose: posterior connexival edges from third to sixth segment (only fourth to sixth visible in winged), and interrupted streak on the connexival suture beneath; luteous: antennæ, coxæ, trochanters, base of rostrum and bands on legs and bases of all femora, remainder of legs infuscated. Hemelytra fuliginous with sparse golden pubescence on corium; corium with a narrow apical white streak; memthe second genital segment projecting beyond like a small blunt knob. Other structural characters as in the winged, except two small, triangular wing-pads.

"Apterous form: Pronotum stout, transversely impressed about one-fourth its length from the anterior margin, two longitudinal impressions from the anterior margin at the eyes meet it, producing deep foveæ at the points of juncture; rounded truncate posteriorly with a somewhat broad explanate margin. Six abdominal segments and two genital visible dorsally, six ventrally (as in the winged); segments, except the first, of nearly equal length, abdomen widest at fifth and sixth segments, with two deep longitudinal lateral grooves. Connexival edges blunt, rounded; genital segment quadrilateral, twice as broad as long, truncated, with the second genital segment projecting beyond like a small blunt knob. Other structural characters as in the winged, except two small, triangular wing-pads.

"Color, brown, as in the winged, except that the specimen in hand is somewhat darker in shade. Silvery pilose, two small anterlateral patches on pronotum, posterior connexival edges from second to sixth segment, posterior middle of third dorsal segment, broadening in fourth and broadly lateral in fifth and sixth, fifth segment with a small posterior median patch. Milk white, vestigial wing-pads projecting beyond posterior edge of pronotum. Winged: long., 5.3 mm.; lat., 2 mm. at humeri. Apterous: long., 5 mm.; lat., 1.7 mm."

From Georgia and Florida.

Velia stagnalis Burm. 1835.

Burmeister, Handb. d. Ent. II, p. 212, 1835; Champion, Biol. Centr. Am. Heter., II, p. 142, 1898 (Comp. notes).

"Of the North American species sent me by my friend Mr. Zimmerman from the neighborhood of Philadelphia, I possess only wingless individuals which are characterized by a yellow brown color, coxæ yellow. Thorax black below. Silver spotted on sides, yellow annulated femora

and tibiæ, small in size (2 lines long). The three last antennal segments very small compared to the first, a character belonging also to the previous species (*V. rivulorum*). The examples are completely developed, having three segmented tarsi and thus can not be larvæ."

"Champion, who examined one of Burmeister's types, says that segments 2 and 3 of the intermediate tarsi are equal in length and that the eyes do not reach the front of the pronotum."

Reported now from Pennsylvania, District of Columbia, North Carolina, as well as West Indies.

Velia brachialis Stal.

Stal., Rio Jan. Hemipt., I, p. 82, 1860; Champion, Biol. Centr. Am. Heter., II, p. 141.

"Winged form. Moderately elongate, brownish-fulvous or brownish-testaceous, the posterior half of the pronotum fuscous; the venter and pleura more or less fuscous, and grayish-pruinose; the antennæ testaceous or brown, with the second joint darker at the base and apex; the legs flavous, annulated with fuscous; the coxæ and trochanters flavous; the elytra blackish-brown, with a long silvery-white streak at the base and three white spots at the apex—the inner one lunate, the others rounded; the body, legs, and antennæ very finely pubescent, and also thickly clothed with long, fine, pallid hairs; the pleura, a spot at the sides of each of the ventral segments, a triangular mark on each side of the pronotum anteriorly, and a spot on both the anterior and posterior sides of each of the femora towards the base, clothed with short silvery pubescence. Head with a smooth, faintly impressed median line; the eyes large and coarsely faceted, reaching the anterior margin of the pronotum; the antennæ long and slender, joint 1 stouter, and fully one-half longer than 2, 2-4 subequal in length, 3 and 4 very slender. Pronotum distinctly punctured, rounded at the apex behind; the junction between the anterior and posterior lobes indicated by four transversely placed punctures and a triangular lateral depression. Legs comparatively stout, rather short; the intermediate tarsi with joint 2 much longer than 3; posterior femora and trochanters very minutely denticulate on their inner edge in the male, and faintly so in the female.

"Male. Sixth ventral segment deeply arcuate-emarginate at the apex.

"Apterous form. Pronotum abbreviated and subtruncate behind; the elytra sometimes represented by a pair of small white wing-pads; the dorsal surface of the abdomen fuscous, the terminal two or three segments more or less clothed with glistening silvery pubescence.

"Length, 4-5; breadth (of the pronotum in the winged form), $1\frac{9}{10}$ mm. Male and female."

Van Duzee gives the distribution as North America, Florida and Arizona.

Velia annulipes Champ.

Champ., Biol. Centrl. Heter., II, p. 142.

"Apterous form. Male. Moderately elongate, robust, fusiform, the body and antennæ obscure ferruginous, the pleura and sterna blackish, the venter fuscous; the legs flavous, annulated with reddish-brown; the coxæ and trochanters flavous; the body, legs, and antennæ very finely pubescent, and also clothed with longer, fine, pallid hairs; the base of the abdomen above, the pleura, and venter greyish-pruinose; the three terminal dorsal segments of the abdomen, the pleura, the sides of the venter, and an indistinct triangular space on each side of the pronotum anteriorly, with patches of glistening silvery pubescence. Head with a smooth, faintly impressed median line; the eyes large and coarsely faceted, reaching the anterior margin of the pronotum; the antennæ

long and slender, joint 1 stouter than, and nearly twice as long as 2, 2 and 3 subequal in length (4 broken off). Pronotum longitudinally carinate in the middle anteriorly, distinctly punctured, rounded behind and with a rather deep transverse groove in front; the propleura extending inwards, and partly separating the anterior from the posterior lobe. Meso- and metapleura laterally prominent. Legs long and rather stout; the femora of equal thickness, the hind pair obsoletely denticulate along their inner edge; the intermediate tarsi with joint 2 longer than 3. Fifth ventral segment broadly produced in the middle behind; the sixth segment very feeble emarginate, with the apical margin thickened. Genital segments very prominent.

"Length, 5 to 6¼ mm.; breadth (of the pronotum), 1⅞ to 2 mm.

"Localities: Arizona (Neotropical).

"A fifth has been added recently, and the description is appended:

Velia watsoni Drake.

Drake, Florida Buggist, June, 1919.

"Head formed as in *V. stagnalis* Burmeister, the smooth impressed median line quite distinct. Eyes globose, strongly faceted. Antennæ long and slender; basal segment curved much stronger, also two-sevenths longer than the second; the second a little stronger than the third; the second, third and fourth about equal in length. Pronotum very coarsely punctured longitudinally carinate in the middle, produced and rather narrowly rounded posteriorly, the tubercles large and prominent. Metapleura with the upward projecting spines visible from above located, as in *stagnalis*, about the middle. First and second abdominal segments (dorsal surface) with a lateral carina on each side. Legs long and rather stout, the under surface of femora and tibiæ denticulate; length of tarsi and tarsal segment proportioned about the same as in *stagnalis*. Antennæ, legs and body pilose and setigerous, the hairs along the posterior margin of the pronotum becoming rather long. Length, male 4.2 mm., and female 4.1 mm.; width, male about 1 mm., and female 1.12 mm.

"Color: general color dark or blackish brown. Legs pale luteous, the bands varying from light brown to fuscous. Eyes black. Antennæ pale brown to brown. Pronotum brown, the posterior portion becoming yellowish brown in the female. Abdomen dark brown, the venter blackish; connexivum (male) with a yellowish brown spot on the anterior portions of each of the last three abdominal segments and the entire connexivum lighter with more prominent markings in the female.

"Described from numerous specimens, collected during the summer of 1918 near Gainesville, Florida. *Type* and *Allotype* in my collection. *Paratypes* in the Florida Experiment Station, Museum of the University of Florida and my collection.

"The eggs are deposited on floating aquatic plants and floating sticks or wood just beneath the surface of the water. The species is predaceous and lives in stagnant water.

"The macropterous form is unknown. The insect very closely resembles *Velia stagnalis* Burm., from which it may be distinguished by its darker color, the much more prominent tubercles in the pronotum and the much longer antennæ. The first antennal segment in *V. watsoni* is much longer than the first antennal segment in *V. stagnalis*, the first segment in the latter and the second segment in the former being equal in length."

B. Biology of Veliidæ.

General Notes. These bugs are for the most part gregarious. Some of them are content to dwell on some small mud puddle and others prefer the rapid waters. All are predatory. Bueno has given us a paper on

the "Veliinæ of the Atlantic States," and also contributed to the biology of two species of *Microvelia*. The writer has reared but one species in this family, *M. borealis*.

Genus MICROVELIA Westw.

The two species that have been reared in this country are *M. americana* and *M. borealis*. The former about the largest and the latter the smallest of the genus. Bueno has published the life history of the latter just recently (Oct., 1917) in *Ent. News*. The writer reared this species in the summer of 1916.

Microvelia americana Uhl.

Habitat. Bueno says: "Many an entomologist when drinking from a field or roadside spring has noticed the tiny black, silver-spangled insects that detach themselves from the stones forming the basin, and run across the surface, or glide out from the side and swiftly curve in to their former resting places. This is *M. americana* Uhl. It is to be found on the banks of any body of water, moving or still. Where the walls of the spring or the bank of the stream or pond are more or less vertical, they perch a little above the water. But on shelving or sloping banks they wander about over the mud or pebbles, seeking their prey, leaving the shore only when alarmed or disturbed. They also conceal themselves under the overhanging banks of streamlets, as observed by Uhler in Maryland, and the writer in New Jersey. . . ."

Hibernation. They hibernate in colonies beneath the overhanging banks of little streams in the middle states. (Uhler.)

Mating. Mating has been described in some detail by Bueno. (See Can. Ent., p. 180, 1910.)

Oviposition. The eggs are white oval bodies, and are placed singly or in clusters fastened to the support by an abundance of transparent gelatinous material, as a rule, just above the surface of the water on pebbles, jutting stones and the like.

Incubation. Bueno says the egg stage lasts two or three weeks or less. The eggs grow darker, and at one end the red eyes, the legs, the rostrum, etc., of the nymph are visible through the shell.

Number of Instars. Bueno describes five instars, each one requiring from 2 to 10 days, the last stage being the longest.

Molting. "In molting the skin of the head splits along the eyes, and rises like a lid at the front. In the body, it splits longitudinally along the middle line of the thorax, and down the dorsum to the third or fourth abdominal segment. The rostral lancets are molted entire, including their insertion in the interior of the head, as well as the tracheæ."—*Bueno*.

The above applies to any other strider. See plate XV for figure of molt of Gerris.

Maturity. These bugs become mature in about 5 days.

Food Habits. The writer has seen them feeding upon insects dropped into the water and catching Ostracods at the surface film. Bueno noted them feeding upon water-fleas imprisoned in the surface film. Bueno says they are always in a condition of semistarvation, and, when a living fly is fed them, of course they attack it in full force. When it struggles

they beat a hasty retreat; but if it quiets but for an instant, they are on it again, piercing it at the joints of the legs or in the sutures between the segments, until the victim of their voracity perishes, exhausted by its struggles and unable to overcome the actively poisonous saliva Microvelia injects.

DESCRIPTION OF STAGES.

The following are taken from Bueno's paper:

The Egg.

"*Size.* Length, .6-.725 mm.; width, .25 mm. to .27 mm.

"*Shape.* Ellipsoid.

"*Color.* Translucent white, more or less glassy. The chorion sculptured in irregular hexagons."

First Instar.

"*Size.* Length, .75 mm.; width, .42 mm., measured from living bug. Head, long.: lat. :: 15:22; eyes: vertex :: 6:10:6; antennal joints 1, 2, 3, 4, 5 : 6 : 5 : 15.

"Antennæ 4-jointed, 1st curved and stout; 2d straight, a little stouter than the 1st; 3d slenderest; 4th slightly slenderer than the 2d, but as stout or a little stouter than the 1st, all thickly covered with long hairs, one long stout hair near the distal end of the 1st joint set in a sense pit and pointing outward; inserted under the head. Eyes exteriorly rounded, set obliquely in the head, occupying a little over one-half the head. Head thickly pilose. Rostrum 4-jointed, rising under the head. Proportions of joints: j1 : j2 : j3 : j4 :: 26 : 7 : 60 : 40. The second joint is annuliform, and the 4th darker and apparently more heavily chitinized than the others. The tylus is slightly prominent. In moulting, the lancets are cast with the skin.

"Prothorax clearly indicated, ring-like; long.: lat.:: 5 : 25, in shape something like a curving collar of even width, sides rounded and sloping forward, thickly pilose. Prothorax and mesothorax fused into one, but an effaced suture visible between them; thickly pilose.

"Legs: First pair shortest, 3d longest. All tarsi single-jointed, claws long, simple, slender, subapical, extending as far again from the tip of the tarsus as the tarsus projects beyond the insertion of the claw. Coxæ and trochanters much elongated in the third pair. First tibiæ with two combs, second with one, apically situated; third tibia with a long, stout subapical spine. First pair of legs, femur longest, then the tibia, then the tarsus, which is stouter than the other two; second pair as the first; third pair, tibia longest, femur next and stoutest, then tarsus, which is more slender than either; all covered with long hairs.

"Abdomen oval, segments well marked, genital segments prominent; all the segments dark, except at the connexivum, which is wholly light; eight apparent segments. The spiracles are seemingly not to be found in this instar, not being visible in either the entire nymph or in the cast skins mounted in balsam, even at a magnification of 530. This, of course, is not a proof that they do not exist, but rather shows how well they are concealed."

Second Instar.

"*Size.* Length, .9 mm.; width, .55 mm.; balsam mount.

"Proportions of head: long.: lat.:: 7 : 10 : eyes : vertex :: 14 : 32 : 14; antennal joints, 1 : 8 : 9 : 20; rostral joints, 9 : 3 : 13 : 10.

"The rostrum extends to the base of the prosternum, or to the insertion of the first pair of legs.

"Prothorax, lat.: long. :: 38 : 6.

"First pair of legs stouter than the other two; the tarsal combs of the first and second pair as before; the third tibiæ armed with a stout double-

pointed spine, apically and exteriorly, and some stout scattered spines interiorly, beginning half-way up to the tibia. The end of the tarsus extends beyond the middle of the claws.

"The abdomen and other details omitted are as in the first instar."

Third Instar.

"*Size.* Length 1.2-1.32 mm.; width .72 mm. to .8 mm. balsam amount.

"Proportions of head: long.: lat. : : 23 : 35 : eyes : vertex : : 7 : 21 : 7; antennal joints, 12 : 10 : 11 : 21; rostral joints, 6 : 6 : 19 : 9 (measured from cast nymphal skin); prothorax, lat. : long. : : 6 : 42. The antennæ and legs grow comparatively slenderer, but the number of joints does not change. The cleft spine on the outer side, subapically, of the posterior tibiæ still persists. The other details omitted are as in the previous instars."

Fourth Instar.

"*Size.* ——

"Antennal joints, 12 : 9 : 10 : 24; rostal joints, 7 : 6 : 17 : 9.

"Owing to having nothing but moulted skins, a number of details must be omitted in this and the next stage of the nymph. The general form, aspect and coloration are as before, the main changes noticeable being in the increasing slenderness of the legs and antennæ. In this and the preceding instars, the spiracles can be seen in the cast skins, as little round openings in the connexivum. In the entire bug I have not been able to locate them. The basal joint of the antennæ is stout and curved, as before, and there is no change in the relative thickness among them. The other details are practically unchanged. The first pair of legs is the stoutest, especially as to the tarsi, and these are single-jointed in all the legs."

Fifth Instar.

"*Size.* Length, 2.14 mm.; width, 1.25 mm.

"Antennal joints, 20 : 13 : 13 : 35; rostal joints, 6 : 4 : 21 : 10. With slight differences, the other details are as before. The tarsi continue single-jointed, with long, simple claws, the posterior tibiæ are spined toward the end, the spines increasing in number from the femoral to the tarsal extremity, and stout in proportions. The cleft spine mentioned before is still present, but is not so noticeable. In this instar, though still greenish in colour, with darker spots, lines and markings, the silvery patches, so characteristic of the adult, first make their appearance. The female can in this instar be already distinguished from the male on account of its larger size, and less prominent genital segments. The males are so much smaller in this instar than the females, that they may be mistaken for nymphs in the fourth instar only. The dimensions of the nymph, taken from the cast skins, mounted in balsam, are not quite accurate, as the skins are much distorted."

Microvelia borealis Bueno.

Habitat Bueno in his recent paper says it has a limited range, doubtless because little collected. He records it for New York, New Jersey, and says Parshley got it in Maine. The writer found it abundant on the margins of a little pool (Cattail pool) near Lawrence, Kan. This pool has dried completely for the past three summers, and it is no longer to be taken there. He found it in both the apterous and winged state, living upon the floating mats of Algæ and dead Typha stems. It was also found at the Brick Plant pool in all stages in July and August.

Hibernation. As an adult.

Mating. As in *M. americana,* described by Bueno.

Oviposition. The writer finds the eggs placed much as in *M. americana,* in a mass of jelly-like material just above the surface of the water and attached to pebbles, stones, etc. Bueno noted them "on the under side of duck weed. The head end pointed to the edge of the leaf." Each egg is upon a stained pad of gelatinous matter as if it had used too much adhesive. When first laid the egg is very white.

Incubation. Bueno gives from 7 to 23 days. The writer has kept many batches under observation in July, and finds the time to be around six days. One lot contained 145 eggs. The darker color and the red eye spots mark the older eggs. Thirty-two eggs laid July 25 showed on the 27th faint yellowish circular spots, which later are the red eye spots. On the 29th they hatched.

Hatching. Bueno says the eggs split longitudinally for 4/7 of their length, and through this the nymph escapes. He looked for, but failed to find, the "amnion or molt." The writer finds that the postnatal molt does occur and that it bears an "egg burster" like the Gerris. One was observed under the binocular to be just coming out. Swathed in the thin membrane it struggles out. The black, shiny knife between the eyes is attached to, and shed with the postnatal molt. Before this membrane breaks, the legs are seen to curl around the tip of the abdomen. The antennæ, beak and legs are outstretched upon the ventrum. See plate XII for figure of the nymph within the egg.

Fecundity. Bueno says a female holds two eggs at a time. The writer noted 6 females that laid 145 eggs in five days. This means nearly 5 eggs per female per day. It takes from 10 to 20 days to reach the adult stage.

Molting. In molting from one instar to the next the process is about as follows: The old integument becomes quite rigid and sets upon the water in a substantial manner. It splits longitudinally for some distance down the dorsum, and the triangular piece between the eyes splits out forward as in the large Gerrids. The antennæ are directed laterally and downward. The newly emerged nymph is white with red eyes. It rests for a time perched upon the old nymphal skin.

Feeding Habits. In the rearings these little bugs were given plant lice and house flies. In shallow petries they make out very well if only there are Ostracods and Daphnians present in the water. The writer has seen little first instar bugs eat Ostracods larger than themselves. It is interesting to watch them maneuvering to pick out an Ostracod that is floating with one surface at the film. The bugs feel around with their little beaks, the terminal segment twisting here and there, playing over the smooth impervious surface for a vulnerable point. If this is not successful they will employ their fore legs in an attempt to roll over the little Crustacean. The Ostracod that moves is the one that attracts their attention and it is sought out and molested by these ever alert and watchful pygmies of the surface. Here one succeeds in driving home his barged stylets and with a backward jerk does an astonishing thing,

presenting to our view a successful catch impaled upon an upturned beak. Here it is held in mid air, till all the nutritive matter has been drawn from within the little bivalve and then it is discarded. If a quick flip of the beak fails to dislodge the carcass, the fore limbs strike it loose.

Description of Stages. Mr. Bueno has published descriptions of four nymphal instars which he says is all of them. The writer has found more than this in some. Before publishing his results, he wishes again to rear this bug to see if here is variation, or whether apterous forms have less than winged, etc. No bugs have been secured for this purpose the past two seasons. Plate XII shows the nymphs, adults and eggs.

Summary. The Microvelias winter as adults, place their white oval eggs on stones, etc., just above the surface of the water. They are predaceous creatures, feeding on organisms reared below and above the surface. Several generations are possible in a season.

Genus RHAGOVELIA Mayr.

These bugs inhabit rapid moving waters, one species *R. plumbea* "is a denizen of estuaries, bays and other brackish or salt waters on our southern coasts and about the Antilles." They possess a most ingenious structural device for making progress on moving waters. Bueno has figured and explained the action of the rowing equipment of *R. obesa.* This species he says can be found in almost any swift streamlet in little congregations, weaving zigzags where the current is most rapid, swimming against it, or else sheltered in the eddy behind some projecting rock, where, in the latitude of New York, the rare, winged form is most likely to be found.

As elsewhere noted, the long terminal tarsus of the middle leg is cleft and in this cleft is a tuft of ciliated hairs. The tarsus is in contact with the water along its entire length, with the slit vertical to the surface. When in this position the spread tuft of hairs projects beneath into the water and is a powerful auxiliary in swimming. See plate XI. When swimming under water the hair tuft is also expanded and is of great assistance.

Mating. Bueno describes the mating in his paper in Can. Ent., Feb., 1907. In June and July the schools are made up largly of sexes in copula, he says.

The Nymphs. "The young nymphs betake themselves to sheltered and still nooks along the bank."

Behavior. Rhagovelia dives and swims well under water. To get below the surface the head is ducked down, and a few quick strokes with the middle legs submerges it.

Feeding Habits. Feeds upon other insects.

Genus VELIA Latr.

We have four species in this country, but little is known of their biology.

Habitat. So far as the writer knows, all of these dwell on flowing waters. Our information regarding the habits and life history deals with European species.

Hibernation. Wessenberg-Lund, 1913, says *Velia currens* winters as an adult in moss which covers the stones.

Oviposition. The eggs of the European form are said to be attached to the rocks and vegetation at the surface of the water.

Number of generations. Kulgatz says that *Velia currens* has several generations a year.

Food Habits. Predatory as are other striders.

Summary. This genus needs attention by some one located where there is flowing water. The writer is not thus located.

Notes on the Aquatic Hemiptera.

Under this head are treated those families of Hemiptera which have become adapted to an aquatic life. Like a number of families of the Coleoptera they not only rear their young in the water but continue to dwell therein during adult life.

Family BELOSTOMATIDÆ Leach 1815.

A. Taxonomy of Belostomatidæ.

Family Characteristics. Large, flat, brown bugs, with hind legs ciliated and flattened for swimming. They bear short, flat, strap-like appendages at tip of the abdomen. These are retractile.

Ocelli are lacking. The antennæ are hidden beneath the eyes, four-segmented, and the outer segments produced on one side. The tarsi are two-segmented. In the American forms, the fore tarsi bear but a single claw each, the other limbs two each. The fore legs are raptorial, the femora enlarged, and the tarsal segment broadly joined to the tibia. The middle and hind limbs are natatorial, the tibia and tarsi being somewhat flattened, and the hind limbs, especially, ciliated. The fore wings possess reticulated membranes. These large insects leave the water at dusk and are often noted at the electric lights, to which they are attracted. Thus their common name "electric-light bugs." They are also known as "giant water bugs."

Historical Review. To those of us who gained our names of water bugs from text books of a few years back, it was most vexing to learn that the nomenclature to which we had been exposed was wrong—so badly wrong that we were forced to learn that *Zaitha* was *Belostoma,* that there was no *Zaitha,* and that *Belostoma* was *Lethocerus.* We now have it straight. The genus *Belostoma* was created by Latreille, 1807, for a small Belostomatid. It was Amyot and Serville, 1843, who gave us the name *Zaitha,* which means "olive," and which has so generally been applied to our small Belostomatids. The type they used, *stolli,* however, turned out to be Latreille's *testaceo pallidum.* So we must forget *Zaitha.* Meyr, 1852, founded the genus *Lethocerus* for some large Belostomatid. These differ from Stal's *Benacus* in possessing a grooved fore femur.

Van Duzee lists four genera for America north of Mexico. They are *Belostoma,* Latr., *Abedus* Stal., *Lethocerus* Mayr, and *Benacus* Stal.

They may be separated by the following key to genera.

KEY TO GENERA.

A. Mesothorax with a strong midventral keel, membrane of hemelytra reduced. *Abedus.*

AA. Mesothorax without midventral keel. Membrane of hemelytra not reduced.

KEY TO GENERA—*Concluded:*

B. First (basal segment of the beak longer than the second; furrow of the wing membrane nearly or quite straight. (Size about 1 inch or less.) *Belostoma.*

BB. First segment of the beak shorter than the second. Furrow of the wing membrane shallowly S-shaped. (Size more than 1½ inches.)

C. Anterior femora grooved for the reception of the tibiæ. *Lethocerus.*

CC. Anterior femora not grooved for the reception of the tibiæ. *Benacus.*

The keys to species and their descriptions are omitted for the present, as the writer is aware that Mr. J. R. de la Torre Bueno has been working upon this group for the past few years, and has promised us a paper shortly.

B. BIOLOGY OF THE BELOSTOMATID.

General Notes. The Belostomids, because of their large size and their frequency about electric lights, have been frequently noticed by the layman. With the installation of electric lights in a town, there usually come inquiries regarding these giant bugs. The bugs are sent in with the statement that they have never before been in that part of the country. On the other hand, they have been there, but have not been drawn to the attention of the populace. As an indication of the general interest taken in these bugs note the numerous references to be found in the *American Naturalist* of earlier years. This periodical was at one time of general interest to all biologists and reflected very well matters of general note.

Another interest that is attached to these insects is the fact that in two of the four genera, *Belostoma* and *Abedus*, the males carry the eggs about with them.

All of these bugs live in the water, where they rest as a rule, clinging to some support with the tip of the abdomen in contact with the surface film. All are fiercely predaceous.

Genus ABEDUS Stal.

There are five species of this genus listed for America north of Mexico, by Van Duzee. *A. ovatus, A. breviceps, A. dilatatus, A. macronyx,* and *A. indentatus.* This genus is confined to our southwest—Arizona, New Mexico, Texas and California. Aside from the collecting habitat notes, little has been done on their biology. The eggs are carried upon the back as in Belostoma, as evidenced by material in our collections. Uhler mentions this fact under his discussion of *Serphus* in Cambridge Natural History. The fierce predaceous tendencies of *Abedus macronyx* have been noted by Harvey under the title, "A Ferocious Water Bug." Here he says that the bug is to be found in the warmer streams and ponds of California. Children who wade in these waters have named it "toe pincher." He placed one in an aquarium and its depredations were astonishing. It devoured a 3-inch trout, young frogs, tadpoles, snails, and various smaller fry. He then isolated it and found it would devour

dozens of tadpoles in 24 hours. The prey was caught as it swam near. This bug in his aquarium lurked submerged, coming to the surface for air. He noted it chirping by means of its rectal spiracles. Mr. Harvey also studied the life history which is not indicated by the title to his paper.

Oviposition. "In California (Watsonville) the breeding season is from April to June and during this time from 2 to 4 sets of eggs are hatched. The eggs are glued tight and fast to the back of the male, and there they stay through the whole incubation period. Upon the wing sheath of the male is first spread a drop of mucilaginous adhesive. Into this drop of adhesive are fastened the eggs, one at a time, closely together, at all angles from perpendicular in the center of the clutch to a cant of 45 degrees at the edges of the wing sheaths. From 70 to 175 eggs are deposited upon the back of the male, but not all at one time. Part of them will be deposited one night, and the rest the next or succeeding nights. This work is all done in the dark, and I was never fortunate enough to observe it. If a spot of 2, 3 or more eggs is missed, it is filled in afterwards, and should some of the eggs prove to be infertile, these drop off and are replaced by others as late as the sixth or eighth day of incubation."

Incubation. "Incubation lasts from 10 to 12 days, at the end of which time the egg cases and adhesive nidus that holds them are cast off entire, providing there be no late laid eggs, in which instance, the empty egg cases and nidus remain attached until all are hatched. The cast-off mass of egg cases and nidus resembles a knobbed shield, being oblong-oval, with the concave side toward the male's back. The eggs are 5 mm. long by 1 mm. thick, and are of same color as the parent. During the period of incubation the male spends much of his time aërating the eggs. This is accomplished by gently raising and lowering the wings so that the air taken in at the surface and held under the wing cases is moved back and forth beneath the mass of eggs, and taken up a little at a time. If by any chance the male should be removed from the water for a few hours during incubation, the whole mass of eggs, nidus and all, loosens and comes off."

Hatching. "At the end of incubation, the male comes to the surface and, with his back partly out of the water, the young begin to appear. The first thing seen after the rupture of the egg cases is a pair of beady, black eyes. At the first appearance of the young, the male begins raising and lowering the wings, at the same time going through a jerking maneuver at regular intervals. The young insect is extruded from the egg by easy stages, the hatching being accomplished in from 7 to 25 minutes. At birth the young bug is about 5 mm. long by 2 mm. broad, of the purest white, rapidly changing to a light straw yellow and brown. In two or three hours at most it is of same color as the parent, and if prey be not abundant, very likely feasting on its fellows."

Genus BELOSTOMA Latr.

There have been abundant biological notes in the literature regarding the common species of this genus. Most of these notes are under the heading *Zaitha fluminea.* The above-named species has been reared by Bueno and the nymphs described. The writer has also studied this species and reared it, adding some points to those recorded. Of these smaller Belostomatids there are nine species and two varieties in America north of Mexico, according to Van Duzee. Of these only three are general in distribution. The others are western, or neotropical. Those to be looked for generally are *B. fluminea, B. lutarium* and *B. testaceum.*

Belostoma flumineum Say.

Habitat. Uhler said it "abounds in mud or among the weeds of ponds and streams." Miss Slater found them most abundantly in shallow water quite near the shore, clinging to the under side of aquatic plants, especially *Marsilia.* The writer finds them in the muddy Kansas ponds, clinging to sticks and boards or trash projecting above the surface. In collecting, these facts should be kept in mind. Severin & Severin showed that 32 out of 35 crawled under a bit of cork in the shallow water.

Hibernation. Like the other water bugs, they winter as adults in the trash or mud about the pool. Doctor Welch, in *Nature Study Review* (1912), has noted this in one of his popular papers on water insect life.

Mating.—Mating takes place in the water, and lasts intermittently for hours. Bueno was the first to note that oviposition is frequently interrupted by the female for the purpose of mating.

Oviposition. This is perhaps the most interesting of all of this bug's activities. It was long ago noted that the eggs are carried upon the back, but early writers ascribed this to the female. Miss Slater, 1899, was the first to correct the matter in this country, though she seemed to be unaware of the work of Schmidt, 1895. She first observed that the egg carriers were all males, and later had the opportunity to witness an aquarium struggle in which the female tried to place her burden upon her mate. Bueno described the process at some length:

> "The female places herself on top of the male, her thorax extending outward and her legs hooked under him; now, starting somewhere near the middle and sidling along every little while, she works her way around him as she fastens her eggs on his back by means of the water proof glue secreted for that purpose. The male all the while hangs from the surface, back up, with his legs curled up under him, bravely bearing up under his burden."

The male, he says, dislikes this "forced servitude." Mr. Bueno thinks the eggs are placed in this unusual place to keep them from the voracious appetites of the adults, for he has seen males seize and greedily suck eggs that had been accidentally dislodged.

Incubation. The length of the egg stage lasts from one to two weeks, as a rule. The egg, which is very large in proportion to the adult when

it is laid, swells considerably as the embryo develops within. In fact Bueno has noted that it gains one-half of its first length.

Hatching. The hatching process is an interesting one, and easily observed. A figure on Plate XVII shows the process at its beginning. A rent, transverse to the long axis of the egg, takes place near the micropylar end of the shell. The cap thus formed is gradually pushed off and the bug by successive heaves comes forth. When part way out, the fore limbs can be seen bound and outstretched upon the venter. When the bug is nearly out of the shell it gives a backward heave. The membrane breaks, and as it gradually slips back, the fore limbs are freed and snap into normal position (femora outspread and tibiæ appressed). Shortly the whole animal is free and rights itself in the water, soon swimming out to some support. The whole process may be completed in four minutes.

Behavior of Newly Hatched. The little nymphs have a tendency to cluster together—clump themselves together at the surface. They are ready to strike for food as soon as their exoskeletons harden. The hatching of a given batch of eggs may last for a day or two before the male frees himself from the egg mass. In this case the older, darker nymphs feed upon the more feeble freshly hatched.

Number of Instars. There are five nymphal instars. The total period required for development from deposition of egg to adult was recorded by Bueno for 3 individuals which took 43, 53 and 54 days respectively. The various stages take about a week each, with a longer time for the 5th instar as a rule. One brood, hatched May 21, went into 2nd instar May 26, into 3rd instar May 31, into 4th instar June 6, into 5th instar June 15, and adult June 25, making 5 days for the first, and 10 days for the last nymphal instar, making with the six-day egg stage, a total of 40 days.

Fecundity. Egg-laden males may be taken throughout the warmer part of the year. Bueno has found them in New York from middle of May to the end of August. Here in Kansas they have been taken both earlier and later. The female doubtless lays several batches in the course of the season, each batch, as indicated by the counts on the males, ranging from 65 to 159 eggs. Miss Slater said she found from 75 to 85, but in Kansas specimens it was not uncommon to find as many as 150 eggs on the back of the male.

Longevity. These insects are long lived, living for more than a full year at least.

Food Habits. The nymphs have been fed in the laboratory upon mosquito wrigglers, Corixids and like forms. The literature contains a long list of the food organisms from fish to snails. Professor Todd, in 1883, published a note in *American Naturalist* about a Belostoma ¾-inch long that vanquished a fish three or four times its own length, which was like a dace in form.

Behavior. We are indebted to Severin & Severin for notes on the behavior of these bugs. They found them positively thigmotactic. As to

food reaction Belostoma rests obliquely in the water. If hungry, they respond to any impact in the water and will, on occasion, employ all their limbs to hold some obstreperous prey.

DESCRIPTION OF STAGES.

Egg Stage.

Size. 2.66 mm. long; .9 mm. in widest diameter.

Color. Silvery gray, the top appearing darker to the unaided eye, and opaque white through the binocular. A brownish spot appears to one side of the top. This is the micropylar area. An irregular tracery of hexagonal figures can be discerned upon careful scrutiny.

Shape. The general shape is best shown by the drawing on plate XVII. It is an elongate cylindrical form, rounded on anterior end, more pointed on posterior. The eggs and egg masses often appear grey and fuzzy, due to colonies of Epistyllis and Vorticella. The pointed end of the egg is set into a transparent gelatinous plate. This plate can be removed from the bug, carrying all the eggs with it. It is pliable when fresh and looks like a sheet of agar-agar.

First Instar.

Size. Total length, 4.6 mm.; greatest width across abdomen, 2.35 mm. The other measurements are shown in the chart with those of the other instars below.

Color. Dorsum: brown, thorax with a few lighter markings and abdomen decorated with light areas in 6 rows. The marginal spots large and rectangular. There is a faint series of median dots on the abdomen, which is extended forward across the thorax and head as a slender light line.

Venter. Smoky brown, barred with pale yellow. The eyes dark red; fore femora barred; fore tibiæ with 2 broad yellow bands. All the femora bear 2 yellow bands and the remaining tibiæ 2 yellow bands.

Shape Much as in adult. Relative distance between the eyes greater.

Structural Peculiarities. The tarsi are all 1-segmented and armed with two claws each. Bueno says the antennæ are short club-shaped, and 1-segmented, about 1½ times as broad at the base as at the apex, and twice as long as the greatest diameter. The ventral portion of the abdomen is densely clothed with minute hairs, the metasternal shield present but not relatively as large as in the older forms. Spiracles evident, caudal pair much larger and guarded by hairs in such a manner as to provide a channel to margin of abdomen.

Second Instar.

Size. Length, 5.75 mm. to 7 mm.; width, 3.2. Other measurements on chart.

Color. The pattern about as in first instar, but general color much lighter, the dark brown of first instar being replaced by a lighter greenish brown, with the bars reaching the lateral margins more pronounced, due to a darker smoky coloring. The ventral aspect much lighter than in the first instar.

Shape. Broader than in first instar.

Structural Peculiarities. The fore tarsal claws which were nearly equal in the first instar are now very unequal, one being greatly reduced. See plate XVII, figures 8 and 9. "The antennæ are now distinctly 2-segmented and a little more slender, basal segment being about half as long as the second."—*Bueno*

Third Instar.

Size. Length, 8 to 9 mm.; width 3.7 to 4 mm. Other measurements on chart.

Color. Dorsum: General color olivaceous; eyes very dark red. The head and thorax mottled with light spots. Meso- and metathorax each with two light spots on their fore and rear margins, giving the effect of each segment being banded with a dark band. This pattern continues along the lateral edge of abdomen producing a similar effect. Besides these six light areas on either side, there are two other rows on either side consisting of more or less rectangular spots.

Venter: General color gray with a yellowish tinge. Femora, trochanters and coxæ of all legs nearly colorless. Tibiæ yellow banded with dark, all tibiæ with 3 dark bands; tip of fore tarsi marked by dark band; tips of other tarsi slightly darker than remaining part. Tips of all femora dark banded. The prothorax is crossed on either side by a black submarginal band, these bands slightly constricted across the mesothorax and fork into two as they cross the metathorax. Base of the abdomen is marked on first three segments with some black. The remainder is gray with the checkering or banding of the flattened sides of the bug as described for the dorsum.

Structural Peculiarities. The antennæ are distinctly 3-segmented, still club shaped, and about twice as long as wide. The wing pads are as in figure on plate XVII. They extend back on the metathorax so that the marginal exposed line of this segment is about one-third the entire line of meso- and metathorax together.

Fourth Instar.

Size. Length, 11.5 mm.; width, 6.3 mm. Other measurements on chart.

Color. General color as before. A dark band on the margin of vertex and a submarginal band on prothorax.

Shape. About as before. The wing-pads now reach about four-fifths of the total marginal length of the meso- and metathorax taken together. See plate XVII. The antennæ are developing two lateral processes in this stage.

Fifth Instar.

Size. Length, 16 mm.; width, 8.5 mm. to 9 mm. Other measurements below.

Color. Deeper than in previous instars. Wing-pads greyish green; abdomen yellowish green with the barring effect along lateral margins.

Structural Peculiarities. Wing pads now reach a trifle beyond the metathorax. The antennæ more like those of the adult. There is still but one segment to the tarsi which become 2-segmented in adult.

TABLE OF MEASUREMENTS IN MM. OF INSTARS OF *B. FLUMENIA.*

Stage.	Approximate length	Body Widths.					Hind Leg.			Middle Leg.			Fore Leg.	
		Head width	Width between eyes	Width rear margin prothorax	Width rear margin metathorax	Length beak	Femur	Tibia	Tarsus	Femur	Tibia	Tarsus	Femur	Tibia and Tarsus
1st instar	4.6	1.4	......	1.5	2.	1.	1.75	1.5	.8	1.38	1.2	.55	1.4	1.25
2d instar	5.5	1.66	......	2.	2.75	1.5	2.2	2.1	1.	1.8	1.6	.75	1.75	1.5
3d instar	8.	2.1	1.	2.6	3.4	1.75	2.9	2.7	1.4	2.5	2.	.9	2.4	1.85
4th instar	11.5	3.	1.47	4.	6.2	2.35	3.95	3.5	1.75	3.5	2.75	1.25	3.	2.5
5th instar	17.	3.75	1.75	5.95	9.	3.25	......	5.5	2.5	5.	3.75	1.75	3.5	3.4

Summary. This common water bug is found in the trash of stagnant waters where it preys upon other aquatic animals. They winter as adults in the mud or trash of the pool. In the spring they mate and the female places from 65 to 158 eggs upon the back of the male, which is forced thus to carry them for a week or two till the young come forth. Six or seven weeks are required to complete a generation.

Genus LETHOCERUS. Mayr. 1852.

Most of the biological notes in the literature which deal with these insects are given under the generic names of *Belostoma* or *Amorgius*, *Belostoma americana* being a favorite. There are five species belonging to North America north of Mexico. *L. americanus* Leidy, *L. obscurus* Duf., *angustipes* Mayr, *L. uhleri* Montd, and *L. annulipes* H. S. Of these *L. annulipes* and *L. angustipes* are listed as western. The others general.

No complete life history has been recorded for any of these giant water bugs. The notes that have been made concerning these large bugs are sometimes difficult to assign to this genus without the possibility that the observer was watching Benacus.

Habitat. Uhler says *americanus* lives in quiet, fresh or brackish waters. It prefers larger bodies of water however than the little *Belostoma*, which may be found in very restricted pools.

Hibernation. We are indebted to L. O. Howard, 1900, for the record that *L. americanus* winters as an adult. It was found in water under the ice. The temperature of the water was 10° F. The adult Belostomatid was taken alive by H. J. Giddings, of Sabula, Iowa, in February.

Oviposition. In 1876, Dr. Riley read a paper before the American Association for the Advancement of Science, "On the Curious Eggmass of *Corydalus cornutus* (Linn) and on the eggs which have hitherto been referred to that species." "In this he surmised," says Weed, "that the

supposed eggs of *Corydalus* figured in the *Am. Entomologist*, 1868, really belonged to *Belostoma grandis*." Weed, while collecting on the edge of a pond near Lansing, Mich., July 3, 1882, found a mass of eggs beneath a board lying at the water's edge. "They looked fresh and beside them was a living *B. americanus*." In Weed's "Life Histories of American Insects," 1897, he says: "The eggs of the American Belostoma are deposited on pieces of wood or reeds along the margins of ponds, apparently where they will be wet, but generally not directly in the water. They are laid in clusters with from 40 to 60 or more eggs in each. The eggs themselves are about one-fifth of an inch long, oblong, ovate in form, with the general color brown, spotted with black; they are lighter colored below than above, and there is a whitish crescent near the top with a distinct black spot at its apex. This crescent indicates the margins of a little cap which comes off when the young bugs hatch. Green, 1901, figures and describes eggs of *Amorgius indicus*, and Distant, 1903, egg laying of same species.

Feeding Habits. There can be no doubt of the fierce predaceousness of these bugs. Marie Merian, 1726, figures the nymph of a giant water bug sucking the juices from a young frog. Weed records that, "In the breeding ponds of the Massachusetts Fish Commissioners these bugs destroyed so many young fish that the authorities had to take special pains to catch and kill them." Matheson in *Ento. News*, 1907, transmits a letter from Philip Lawrence telling of an attack upon a woodpecker. A woodpecker (an ordinary flicker) was heard to utter cries of distress, and fluttered and fell down out of a tree. A very large bug was found attached to the woodpecker's head. Its beak was inserted in the back part of the woodpecker's head and its legs clamped tightly around the bird's beak. Britton, 1911, records *L. americanus* as capturing a young banded pickerel, *Lucius Americanus* Gmelin, measuring 3⅝ inches long. The writer has found that these bugs will, in the laboratory, make out on pond snails if there be no other fare.

Behavior. The fact that these bugs are to be taken at the electric lights, sometimes far from water, indicates that they are strong fliers, and that they do their migrating from pond to pond at night.

DESCRIPTION OF STAGES.

Egg. Weed gives the egg of *L. americanus* as about one-fifth inch long, oblong ovate in form, with the general color brown spotted with black, lighter below than above, and a whitish crescent near the top, with a distinct black spot at its apex.

The writer has captured *Lethocerus uhleri* and secured egg clusters in the aquarium. One female taken in July laid 4 clusters of eggs one night, 7, 7, 6, and 3 in each cluster, the eggs of which were bound together by a clear, gelatinous material. These eggs are figured on plate XVII and from them may be given this description:

Size. Length, 3.25 mm. to 3.75 mm.; greatest diameter, 1.75 mm. to 2.25 mm.

Shape. Newly laid, irregular ovoid.

Color. Newly laid, pale, grayish green, the outer end of egg blotched with patches of darker color due to a trace of brown. The surface minutely and irregularly hexagonally reticulate, not plainly visible even under low power binocular, but becomes apparent under low power compound. A bit of the chorion mounted on a slide and examined by transmitted light shows a series of irregular hexagonal figures of various sizes. The boundaries of the figures appearing as a tracery of fine white or transparent lines on a brown ground. The egg clusters are held together and to their support by irregularly globose masses of gelatinous like material. See plate XVII.

Summary. These giant water bugs, distinguishable by the presence of a groove in fore femora, are fiercely predaceous creatures of our larger ponds. In their nocturnal migrations from one body of water to another they are frequently attracted to the lights. The eggs of *L. americanus* and of *L. uhleri* are now known. In nature they are laid on reeds above the surface of the water. Nothing is known about the length of the various stages.

Genus BENACUS. Stal. 1861.

There is the one species in this country, *B. griseus* Say. It is the largest of our electric-light bugs. It differs from *Lethocerus* in having less thickened fore femora which are not grooved to receive the tibiæ when flexed.

The biological notes of any extent (aside from collecting) consist of two papers; one by Brimley, *Ent. News*, 1905, describing the walking of *B. griseus*, and the other by Needham, *Ent. News*, 1907. This second paper is a splendid paper, accompanied by remarkably clear photographs of the egg cluster, hatching eggs, newly emerged nymph and adult.

Oviposition. Weed, 1897, tells us eggs are laid in masses on sticks and other rubbish at margin of ponds. Needham, 1907, says that "the egg clusters are two or three inches long, and contain 75 to 100 eggs of a size that for insects is fairly immense. The eggs are attached by one end in more or less regular rows, and they cover in a single layer the broader, flatter side of the stem. They would be conspicuous but for their resemblance in color to the stem." The longitudinal streaking of brown upon a lighter ground, together with the way they are placed and spaced, makes them fall into line with the flutings of the stem, and greatly assist in the concealment of the cluster. The egg clusters are attached above the water line.

The Egg.

(Description from Needham.)

Size. 5 mm. long; 2 mm. in greatest diameter.

Shape. Oblong oval in form with very obtuse ends.

Color. Each egg is marked longitudinally with 20 or more irregular stripes of brown (often interrupted, cleft, fenestrate, or anastomosing, and always with uneven margins) convergent toward the center of the free end upon the upper side. Under a lens the eggs remind one of a pile of Georgia watermelons. If the color were green instead of brown

the resemblances would be perfect. Not only is the shape the same, the "blossom end" being plainly suggested, and the exposed upper side being slightly more convex than the lower, but the streakings fade out below in a very similar manner. However, a closer inspection reveals a different feature at each end. At the free end, just below the "blossom scar," there is an obliquely-placed white crescent, whose arms extend down upon the sides and mark out the cap that the young Benacus will later push off at hatching. The brown lines of the under surface stop short at the edge of this crescent; they are still more abbreviated at the opposite end of the egg. At the basal end the egg is broadly capped with uniform dark brown.

Incubation. Complete period not determined. Dr. Needham found a cluster June 13. It began hatching the 23rd.

Hatching. Dr. Needham secured a splendid photograph of the little bug emerging from the shell. They came out of the egg by lifting a detachable cap of the shell. "The embryo lies once folded within the shell, its head flexed upon its breast, and its beak and legs extended flat against the venter of the abdomen. Thus the dorsum of the prothorax abuts against the detachable crescentic groove. The eyes appear before hatching as black spots upon the arms of this crescent. The back is almost invariably downward, as seen in the figure, though sometimes turned a little to one side. On account of the obliquity of the pale crescent and the constant position of the embryo in relation to it, these eggs might readily be oriented for section cutting in embryology."

"The thin lateral margins of the abdomen unrolling at hatching, and the legs becoming extended, the fledgling at once assumes proportions seemingly wholly incompatible with the size of the egg from which it came."

Family NEPIDÆ Latr. 1802.

Latreille, Hist. Nat. Crust. Ins., III, p. 252 (Nepariæ).

A. Taxonomy of Nepidæ.

Family Characteristics. Interesting water bugs, distinguished from all others by the presence of long, slender caudal filaments which are not retractile. The fore legs are raptorial. The middle and hind legs very little adapted for swimming. The tarsi are 1-segmented. The beak is short and 3-segmented. The antennæ are concealed and ocelli are absent. The wings are reticulately veined.

Three genera in America north of Mexico, *Nepa*, *Curicta*, and *Ranatra*. Only the last genus named is credited with more than one species. It is given seven by Van Duzee.

Historical Review. These strange-appearing bugs were among the first aquatics to be noted in the literature. Frisch, 1727, describes and figures both a *Nepa* and a *Ranatra* under the following names:

"Von der breiten Wasser Wanze mit den zwen Fang-Klauen und der hintern Lufftrohre" and "Von der grossen schmalen Wasser-Wanze mit der Fang fussen und der hintern lufftrohre." This author says that Johnston and Franc Rhedi had mentioned these bugs. Swammerdam

figures *Ranatra* and *Nepa* and discusses them under the title of "The Flying Water Scorpion." Thus from an early date we have biological notes on *Ranatra, Nepa, Notonecta* and *Naucoris.*

KEY TO GENERA.

A. Body broadly oval and flat; legs not extremely long and slender; prothorax much broader than the head; anterior femora but little longer than tibiæ. *Nepa.*

AA. Body elongate oval; legs not extremely long and slender; prothorax little broader than head; anterior femora considerably longer than tibiæ. *Curicta.*

AAA. Body very elongate; legs long and slender; prothorax narrower than head; anterior femora considerably longer than tibiæ. *Ranatra.*

Genus NEPA Linn. 1758.

Body of these bugs is very flat and broad, nearly truncate in front, but pointed behind. The small head is set deeply into the anterior border of the prothorax. The eyes are small but protuberant. Ocelli are lacking. The prothorax is much wider than the head, and roundly incised in front to receive the head. The wings are broad and the limbs short. The front femora being little longer than the tibiæ.

Nepa apiculata Uhl. 1862.

Uhler in Harris Treat. Ins. Inj. Veg. edn., 3, p. 12, pl. 1, fig. 1.

The following description is taken from the Standard Nat. Hist., vol. 11, p. 253, 1884:

"Color dull fuscous grey, with the base of the abdomen above more or less tinged with reddish. It is of an elliptical form, blunt in front, with a ridged middle line on the vertex, and with three short raised lines on the prothorax, each side of a longer one on the middle. The surface and margins of the thorax and head are roughly granulated, while these, together with the scutellum and corium, are rough and closely covered with stiff, short pile. The anterior femora have no teeth on the inner angle, but instead there is a prominent elbow, forming a wide expansion for the sides of the deep gutter. The wings are smoke brown, with darker veins. This species closely resembles the European one, and measures about two-thirds of an inch to the end of the abdomen; while the respiratory tubes are a little more than one-fourth of an inch in length. Montandon has shown the differences between our species and the European *N. cinerea* Linn."

Curicta howardi, Montd. 1910.

Montandon, Bul. Soc. Sci. Bucarest, XVIII, p. 181. 1910.

"Of form elongate oval, visibly attenuate in front and behind, lateral edges not subparallel, its greater width situated toward the posterior third. Head quite enlarged, although a little narrower than the front part of the pronotum, as long as wide, including the eyes, longitudinally carinate throughout its length, the carina more obtuse on the posterior interocular portion. Interocular space more than three times as wide as the diameter of the eye. Eyes little, globular, anterior part of the head triangular, exceeding the anterior level of the eyes by a length equal to its width between the eyes in front.

"Pronotum very visibly longer than its width behind, lateral edges subparallel on their anterior three-fifths, quite strongly widened on their posterior two-fifths; with four obtuse longitudinal carinæ, little accen-

tuated and subparallel, two each side on the anterior part, the posterior part with two oblique carinæ arising from the anterior median carina and quite divergent behind. The anterior depression of the pronotum largely semicircular, with the anterior angles quite narrowed, in almost right angles, subacute.

"Scutum with three longitudinal carinæ, the median continuing quite plainly clear to the apex of the scutum, the two lateral slightly diverging behind, vanishing on the middle of the sides of the scutum, which are slightly sinuate before the end.

"Coria insensibly and gradually widened behind on their basal halves, giving their greatest width behind the middle and narrowing thereafter; membrane well developed, regularly subrounded at the extremity. Commissure of the clavus almost twice longer than the scutum.

"Appendages short, quite robust toward the base, attenuated thereafter, about half the length of the abdomen.

"Anterior femora quite robust, as long as the pronotum on its lateral edges, with a single median tooth easily visible on the inner edge of the groove where the folded-up tibia is lodged, this tooth is very visibly closer to the base than the apex of the femur; the external side of the groove appears also denticulate, as if notched on the basal third of the femur. Neither teeth nor sinuosities toward the apex of the femur.

"Anterior coxæ half the length of their femora. Anterior tibia quite long, blackish, with a pale annulation toward the base and the apical thirds likewise pale; the extremity of the tarsi come to the basal third of the femur when the tibia is folded back against the latter.

"Intermediate and posterior legs short, the end of the posterior femora, which are a little shorter than their tibiæ, do not reach the suture of the last abdominal segment. Intermediate tibiæ a third shorter than their femora. Intermediate and posterior tarsi with their claws less than half as long as their tibiæ.

"Median longitudinal part of the prosternum slightly saddle-backed, projecting in all its width, more elevated than the lateral pieces, a little flattened and traversed its whole length by a fine median groove; very obtusely tuberculate in its anterior part.

"A greater space between the intermediate coxæ (hanches) than the anterior or posterior coxæ.

"Length, 19 mm.; maximum width a little behind the middle of the corium, 4.5 mm.; at base of the pronotum, 3.8 mm.; length of appendages, 7.7 mm.

"Victoria, Tex., a single specimen, U. S. N. M."

Genus RANATRA Fabr. 1790.

The bugs of this genus are long and very slender, resembling the sticks and trash amongst which they lurk in the water. The body is cylindrical and elongate. The head small and triangular and the beak short. The eyes are prominent. The prothorax is elongate cylindrical, and not as wide as the width across the eyes. The fore legs are raptorial, with the femur much longer than the tibiæ. The middle and hind limbs are slender and long, and serve it well in creeping about in the submerged trash or vegetation. Van Duzee lists seven species for America north of Mexico. One of these, *Ranatra grisea* Bueno, has no description and is only a manuscript name. It appeared in Bueno's list of Heteroptera in Smith's Insects of New Jersey, 1910.

On the other hand, Van Duzee places *kirkaldyi* Bueno as a synonym of *R. fusca,* and Mr. Bueno assures me it is a good species. The description in literature is unsatisfactorily brief.

Montandon says that *R. annulipes* is synonymous with *R. fabricii* Guer, overlooking the dates in the matter. However, as the writer stated in the beginning, the responsibility for these matters rests with Van Duzee whom he has faithfully followed.

Ranatra americana is the commonest one of these insects in the United States, says Montandon. In spite of the careful notes of comparison made by the above-named writer, it is not possible to prepare a satisfactory key without carefully examining much material. The writer would refer his Ranatras to Bueno for determination.

Ranatra fusca P. B. 1805.

Palisot-Beauvois, Ins. Rec. Afr. Am., p. 235.

"Greenish fuscous, setæ shorter than the body, wings reddish fuscous." Bueno says this latter character is quite noticeable and adds "that the anterior femora are narrow, smooth, save for the middle tooth; that *R. fusca* can further be differentiated from *R. quadridentata* by the much longer legs, the tarsal claws reaching nearly to the extremity of the air tube and the extremities of the femora of the third pair of legs attaining to the end of the penultimate abdominal segments; by the prominent eyes; by the prothorax being slimmer and longer and unisulcate beneath.

Ranatra kirkaldyi Bueno 1905.

Bueno, Can. Ent., XXXVII, p. 187.

"Abdominis dorsum orange brown; eyes small, not very prominent; prothorax much constricted at the middle, bisulcate beneath; wings smoky; anterior femora broad, with a prominent tooth near the middle, otherwise smooth; posterior tarsi extending beyond the middle of the air tube; air tube shorter than the length of the abdomen; legs banded; length from tip of abdomen to tip of rostrum, male 23 mm.; 26.4 mm.; female, 27-31 mm."

Ranatra nigra H. S. 1853.

Herrich-Schæffer, Wanz., Ins. IX, p. 32. 1853.
Montandon, Bul. Soc. Sci. Bucarest, XIX, p. 64. 1910.

Montandon makes the following remarks regarding this species:

"Size almost of *R. linearis;* darker; eyes no larger but more projecting; vertex broader; structure of thorax and length of legs as in *R. elongata.* I know of no North American species with legs as developed as those of *R. elongata* Fabr. The posterior femora of which extend backward plainly surpassing the last abdominal suture."

He concludes that it could not be confused with other species of North America.

Ranatra americana Montd. 1910.

Montandon, Bul. Soc. Sci. Bucarest, XIX, p. 65.

"This is the species most common and widespread in a great part of North America, at least in the east and southern part of the United States. My collection possesses examples from Lowell, Mass., Pittsburgh, Pa., Long Island, N. Y., Lake Forest, Ill., and Florida. It has been confused probably by the majority of authors with *R. quadridentata* Stal., with which it differs in the size, being a little more robust (forte), in the form of the eyes, which are a little larger, more prominent and plainly transverse, as broad as the interocular space, which is also

more convex than with the true *R. quadridentata* Stal., the cheeks sensibly more elongated and more prominent in front of the eyes, subparallel, a little attenuated in front, but not divergent at the summit, better applied against the tylus, which surpasses it, also very sensibly in front, which gives to the anterior part of the head a form a little more elongate in front of the eyes.

"Pronotum very visivly narrowed in the middle, enlarging insensibly in the rear and in front. This character permits one to distinguish quite easily this form from the true *R. quadridentata* Stal., with which the median constriction of the pronotum is a great deal less marked (assuse) and the anterior part more cylindrical.

"The majority of the examples of this species have the double tooth at the extremity of the anterior femur, which has confused it with the true *R. quadridentata* Stal.; but this double tooth is often very attenuated and sometimes even altogether atrophied. I have distinguished this latter example under the name of *R. americanus* var. *edentula.* It is represented in my collection by two single female examples, one from Pennsylvania, and the other from Texas."

Bueno, in his "Three Ranatras of N. E. U. S.," states that the legs of *R. quadridentata* are not unduly long, the tarsal claws of the third pair barely going beyond the middle of the air tubes, and the extremity of the femora going but little beyond the anterior margin of the penultimate abdominal segment. The eyes moderately large and the prothorax more stoutly built and bisulcate beneath.

Ranatra brevicollis Montd. 1910.

Montd. Bul. Soc. Sco. Bucarest, XVIII, p. 184.

"It is indeed regrettable that I have described this new form from one unfortunately unique specimen, very little dissimilar, at first sight, from *R. quadridentata* Stal., but its specific characters do not permit it to be confused with the other species, *fusca* or *quadridentata*, from which it differs by its anterior femora being very slightly sinuate toward their extremities. It also has a single tooth before the median sinus of the femur. A little more thick-set, of form less elongate than *R. fusca* Pall de B., which would bring it closer to *R. quadridentata* Stal. It is separated as plainly from this latter form by the much shorter form of the pronotum. In fact, the insect is 34 mm. long, of which length the head and pronotum have only 10 mm. The appendages of 22 mm. are sensibly shorter than the abdomen. The intermediate and short posterior femora, folded forward, scarcely surpass the head.

"The pronotum very robust, about a third as long as the abdomen, quite strongly dilated in front, and very strongly enlarged behind, does not allow confusion with *R. kirkaldyi* T. B. It is, besides, marked by two longitudinal grooves, slightly oblique on the sides, behind the anterior dilation, not attaining behind the transverse grooves which limit in front the posterior dilated part of the pronotum. This latter marked by a longitudinal median carina disappearing behind, less emphasized in front, where it traverses the transverse groove which limits the posterior dilated part.

"The legs are very slender, a little shorter proportionally than those of *R. quadridentata* Stal.; femora reddish, marked by pale, wide, little visible annulations.

"Metasternum in a plate (metasternal plate) terminated in the middle behind by a narrowed prolongation between the posterior coxæ, appearing more elevated than in *R. fusca* P. de B. and *R. quadridentata* Stal., but less, however, than in *R. fabricii* Guer.-*annulipes* Stal.

"This species, however, is distinguished from the three other known

forms of North America by the genital opercule extending a little under the base of the appendages. The ventral segment which precedes the genital opercule almost straight on its longitudinal summit, very little convex before the extremity.

"The interocular space convex between the eyes, but without trace of tubercle, scarcely wider than one eye. The eyes very slightly transverse.

San Diego, Cal., coll. Coquillet, U. S. N. M., Washington.

Ranatra protensa Montd. 1910.

Montandon Bul. Soc. Sci. Bucarest, XVIII, p. 185.

"Almost of the same size as *R. fusca* and *R quadridentata;* length, 36.5 mm., of which 12.5 mm. are for the head and pronotum together, and 24 mm. for the abdomen; appendages quite robust, much shorter than the abdomen, 18.8 not altogether 19 mm.; intermediate and posterior femora quite long, 16 to 17 mm. (They are spread out at the sides in the specimen examined, but brought back behind the posterior one attain the last abdominal suture.)

"Eyes visibly transverse, as wide as the interocular part which is not regularly convex. but very obtusely elevated in the middle, as for the base of a tubercle. Cheeks converging in front, fitting most closely at the extremity against the tylus, regularly narrowed, not protuberant, the tylus slightly surpassing them in front. This character of cheeks attenuate and converging in front distinguishes this insect from all other North American forms in which the cheeks project, almost diverging at the apex of each side of the tylus.

"Anterior femora quite slender, but scarcely a fifth as long as their coxæ, without trace of tooth or sinuosity near the extremity, and with the median tooth of the lower inner side very little elevated, obtuse and little distinct. The anterior coxæ almost as long as the pronotum on the side; coxæ and femur together scarcely longer than the intermediate or posterior femora; anterior tibia very short, scarcely a little more than a third of the length of the femur.

"Metasternal plate a little convex, well prolonged behind where it is lost between the posterior coxæ with the first abdominal segment which resembles in the middle a fissure, narrowed at the extremity of the metasternum, all as elevated as the plate.

"*Memes cories*," with membrane covering up the suture of the last abdominal segment, as in the other American species. Pronotum quite dilated in front, not much more dilated behind than in front, feebly carinate on the anterior part. The prosternum is hollowed out in all its width clear to the middle of its length; the bottom of the hollow is flat without groove behind the coxæ, the lateral sides elevated, vanishing behind.

"The specimen, unfortunately unique, is pale yellowish ochre; the intermediate and posterior femora with some vague clearer annulations."

Long Island, New York, U. S. N. M., Washington.

"This species has a little of the appearance of *R. brevicauda* Montand. of South America, but in this latter the cheeks are projecting; almost diverging at the summit of each side of the tylus; the genital opercule surpasses sensibly the extremity of the abdomen and the more robust appendages are also proportionally shorter; but it has almost the same form of vertex; by contrast, the anterior femur has a median tooth indeed stronger on the lower inner side and the lower outer side, also has an obtuse prominence at the place where the end of the anterior tarsus comes when the tibia is folded back against the femur, and farther from the end of the femur than the lower inner tooth."

Ranatra annulipes Stal. 1854.
Of. Vet. Akad. Forh., XI, p. 241.

B. Biology of Nepidæ.

General Notes. These water bugs are to be taken by raking the mud and trash out of the water. They swim but little, spending most of their time motionlessly awaiting the close approach of some unwary creature. Their raptorial fore legs are usually set before them, and are capable of striking forth with lightning rapidity. Once the insect or other little animal is caught in the vice-like grip there is little chance of escape. The broad flat *Nepa* is likely to be found in the mud or leaves at the edge of the pool, while the *Ranatras* may be taken in trash in waters of various depth. The flat, dirty, roughened coat of the former, and the long, slender shape of the latter give these bugs an aggressive resemblance to mud and tangled trash respectively. When going through open water, the legs are moved alternately, making the gait, as Kirkaldy suggests, a paddle rather than a swim.

Genus NEPA Linn.

The one species in this country has a general distribution east of the Mississippi river. The writer has taken it at Ithaca, N. Y.

Habitat. It is a mud-loving bug, and usually found in raking out mud and trash near the water's edge. Bueno (Can. Ent., XXXVII) says *N. apiculata* is found in shallow water, not much over two or three inches deep, concealed in the mud or in situations where grasses grow out of water clinging together.

Hibernation. It winters as an adult, and has been taken in winter collecting.

Mating. Roesel, 1755, said that Nepa remains paired two days and nights. Hewitt, 1906, figures and describes the mating of *Nepa cinerea*

Oviposition. The peculiar eggs of these bugs bear seven filaments.* They are inserted in the tissues of decaying plants. These were figured many, many years ago by Swammerdam, 1737. Roesel, 1755, stated that they were dropped to the bottom. Geoffrey said the eggs were laid in the twigs of *Scirpus* or some other aquatic plant. Recently we have Wesenberg-Lund's statement, 1915, that the species of his country lays its eggs at night and he figures them in moss plants. Brocher, 1913, says their Nepa lays in April and can be found in October with eggs completely formed ready to lay. The number of filaments he says are variable. "Authors have indicated seven, but the eggs which I have had the occasion to observe had eight or nine. The eggs are fixed in the skin of plants in or floating at the surface, only the filaments resting exteriorly."

Hatching. Brocher says at the moment of hatching the anterior extremity of the eggs is opened like a lid of a box and the larva comes forth. He figures the hatching process giving 6 figures. The larva

* Our *N. apiculata* lays eggs bearing 11 filaments.

lacks the siphon. De Geer said that the young come forth in the middle of the summer, the complete development taking two months.

Number of Instars. We are indebted to Roesel, 1855, for figures of all five nymphal instars of the European bug.

Food Habits. This bug does not pursue its prey to any great extent; but lies in wait for it. Its flat body enables it to float with more stability on the surface film than its relative Ranatra. The photograph on plate V shows the result of placing two bugs in a deep aquarium without any trash for support. When the two bugs encountered each other at the surface the smaller Nepa won the fight. Wood, 1884, says its food is mostly the larvæ of May flies and whirligig beetles. Kirkaldy, 1906, says they are seemingly content with Daphnia and Cyclops, but suck fish eggs, and even attack small fish and tadpoles.

Behavior. Severin & Severin have studied the behavior of these insects somewhat, together with Ranatra. Nepa has interested biologists from an early date, for Mouffet, 1634, figured it. Frisch, 1728, also figured it. See plate IV.

Description of Stages. The egg has been figured and described from Roesel's time to Brocher's. The nymph described by Roesel, 1746-'61; Burmeister, 1835; and Kirkaldy, 1911. Walter Dogs, 1908, gives some structural details in his "Metamorphose der Respirations organe Bei *Nepa cinerea.*"

The Egg.

Brocher describes the egg of the European form as follows:

Size. "2.5 mm. long.

Color. "Whitish yellow. Rosette of filaments at the tip, number of these varies from 7 to 9."

The writer has found as many as 11 well-developed ova in one female *N. apiculata* in July. On plate XVIII is a figure of one of these. The description follows:

Egg of *Nepa apiculata.*

Size. Length, 2.8 mm.; width, 1.35 mm.; length of filaments, .96 mm. to 1.05 mm.; diameter of the crown, .42 mm.

Shape. An elongate oval, irregular in outline; somewhat pointed at one end. The other end bearing on one of its slopes a crown of eleven slender filaments arranged in a circle. See the figure on plate XVIII.

On one side near the pointed end and diagonally across from the center of the filamentous crown is a circular raised area.

Color. Pale yellow; filaments whitish; the raised circular area dark.

Genus RANATRA Fabr.

We have here many more biological notes than for Nepa. Bueno has given us a fairly complete account of *Ranatra quadridentata.* In fact more has been written about the biology of this group of water bugs than any of the others. Aldrovandus, 1602, under the name of *Tipula aquatica* mentions it. Swammerdam calls it *Scorpius aquaticus.*

Habitat. Found in the tangles of trash and vegetation in the water. Kirkaldy and Lucas both record that Ranatra is at home in the mud at

the bottom. Bueno says *R. quadridentata* frequents deep water, where it clings quite fast to the stems of rushes or grasses, with its air tube piercing the surface film. The writer has found this common enough in pools where weeds had lodged, and also upon the floating dead leaves and stalks of cattail, where they were basking in the sun and entirely dry.

Hibernation. Bueno says that *Ranatra* winters as an adult and is sometimes found frozen in ponds. Marshall and Severin, 1904, note that they were found in mud at the bottom of pools or creeks in winter. This seems as good a place as any to record the splendid observations of Wessenberg-Lund "Uber die Respirationsverhaltnisse bei unter dem Eise uber winternden, luftatmenden Wasserinsekten, besonders der Wasserkafer und Wasserwanzen (1910-'11)." There is an English summary at the end of this interesting paper which is here quoted:

"It is a well-known fact, that air-breathing insects, especially *Dytiscidæ, Hydrophilidæ* and waterbugs hibernate beneath the ice. For several months these animals which, as far as we know, do not possess any other organ of respiration than the open metapneustic tracheal system, though totally excluded from the air, sustain life in the ice-covered lakes. Observations through the ice as well as in ponds, from which the ice had been removed, show that the animals do not, like frogs, bury themselves in the mud, but at any rate, during the first winter months, are swimming about lively beneath the ice.

"Now, it has been shown that water insects especially in the fall at night-fall, disappear from ponds with slight vegetation, where they often made their home in summer and have laid their eggs, now going in search of localities with rich vegetation, more especially bubbling springs or ponds, where the beach is covered with green plants. Numerous observations in nature further show that the green plants, especially during the first winter months, produce great quantities of oxygen. Like silvery bubbles the oxygen covers the plants and later on accumulates beneath the ice. According to experiments in the laboratory and observations in nature it may be supposed that this oxygen during the first part of the winter forms the respiration air of the animals. Later on, when the vegetation dies off, the production of oxygen decreases, and methane and carbonic acid accumulates beneath the ice, the bubbles will not suffice to meet the claims of respiration. In what manner then are the animals able to sustain life beneath the ice during the two or three last winter months? The present paper shows, that insects, which in summer die, when only for a few minutes or hours excluded from the air, in winter at a temperature near zero are quite able for months to support a total exclusion from air. When every possibility of getting air fit for breathing is excluded, it seems that the animals settle down in a winter sleep, or 'Kaltestarre,' in which respiration is extremely lowered. In our country this winter sleep principally takes place in the *Fontinalis* carpets, which cover the bottom of a great many ponds and small lakes. It has been supposed that respiration through the integument plays a much greater part than hitherto believed. It has been emphasized that the views and suppositions set forth in this paper should be subject to thorough experimental explorations in physiological laboratories."

He saw an adult *Ranatra* swim under 3 cm. of ice; noted that other bugs also do this and also that the large fat bodies and small eggs commonly noted in the fall are reversed in the spring.

Mating. Bueno says that in mating the male is below and to one side of the female. The process as noted by the writer is a prolonged one. The sexes may be distinguished by the figures on plate XVIII.

Oviposition. Wessenberg-Lund says that with Ranatras the eggs are laid in early morning. Fred Enoch, 1909, gives the most complete account we have. His observations were upon *R. liniaris:*

"Last week I had the pleasure of observing the female engaged in ovipositing on a floating leaf of *Alisma,* the edges of which were tightly grasped by the second and third legs, while the first were held close together, high up on a line with the body, which slanted down from the head at about an angle of 30 degrees, the head being an inch above the leaf. The ovipositor was extruded, and the tip pressed by a downward and forward movement into the leaf, until forced through, when it was partially withdrawn, opened, and an egg placed in the hole. The long lateral filaments sprung open as the ovipositor was withdrawn. She moved along a quarter of an inch, and the process of boring the hole repeated, the long respiratory tubes resting on the fork of the last laid, which was pressed home until the tip of the egg was just level with the surface of the leaf. The eggs are also laid in half decayed stems of Alisma, and sometimes, though not so frequently, in healthy green stems. I have several times bred *Prestwichia aquatica* Lubbock from eggs of Ranatra."

The writer has not seen the process, though he has watched for it a number of times. He disturbed one in the act at Beebe Lake, July 11. Eggs were laid in large numbers in a pool on Six Mile Creek, near Ithaca, N. Y., during June. A visit to this pool June 4 found *Ranatra* eggs abundant on top of floating dead Typha, some of them showing the red eye spots. The photographs on plate VII are of some of these. Pettit, 1902, gave some very good drawings of *Ranatra* eggs which he described.

Incubation. Latreille said, "Ils restent quinze jours au fond de l'eau." Kulgatz says *R. linearis* is in egg stage two weeks. Bueno gives two or three weeks for the incubation period. In one aquarium the writer found eggs deposited on May 11 hatched June 14. This was at Ithaca, N. Y.

Hatching. Bueno says the young emerge through a round cap at the top, which bears the filaments. Brocher gives a similar brief account. In hatching the nymph casts a clear membrane, post-natal molt, which it leaves as a diaphanous mantle, crumpled into a shapeless mass, and clinging at its caudal end in the fissure of the shell. See plate XVIII. No hatching "burster" is discernible under high power binoculars. Holmes 1907, says "When one sees a Ranatra on emergence from the egg he cannot but be surprised that the young insect should have been inclosed in so small a receptacle. The body of the nymph is as broad as the egg and over twice as long."

Number of Instars. There are five nymphal instars. Bueno reared one to the adult stage and found that the first instar lasted 8 to 14 days; the second 9 days; the third instar 7 days; the fourth instar 8 days; the fifth instar 8 days. "A total of 61 days from egg to adult."

Fecundity. The writer believes that these bugs produce many eggs, because in one restricted pool where there were few Ranatra the eggs were very abundant.

Food Habits. Here there is a long list of references dating to an early time. The food of the young, says Holmes, "consists chiefly of small

swimming forms, chiefly small crustaceans and insects which come near the surface of the water. Like the adults, they are very efficient enemies of mosquito larvæ. They do not pursue their prey, and seldom catch forms that keep close contact with solid objects. They are like so many traps set and respond to an impact upon the water." He observed one very young bug catch an Ostracod which closed up and escaped.

Ormerod in the Ento., XI, p. 95, gives the economic side to the foraging of this bug. Record is made of its attack upon the spawn of fish. The only method of ridding the ponds was to drain them dry and restock with fish. Swammerdam's account still stands as a good one. "There is not perhaps in all the animal creation so outrageous or fierce a creature against those weaker than itself than the water scorpion. It destroys, like the wolf among sheep, twenty times as many as its hunger requires. I have often seen one of these when put into a basin of water in which were 30 or 40 of the worms of the middle Libella, which are at least as large as itself, destroy them all in a few minutes." Bueno has found that their food consists of those unwary insects that fall into the water. The writer thinks that much of their food consists of such May-fly nymphs * as clamber about in the same environment. These it captures as they swim by.

Behavior. Holmes and Severin have studied the behavior of these insects. In Holmes' "Evolution of Animal Intelligence" are several notes. He finds it negative to light when first brought to light from the dark, but this soon gives way to a decided positive response.

Bueno, 1903, published an interesting account of the stridulation of *Ranatra.* When one of these insects is lifted out of the water it often gives forth a peculiar squeaking sound. The writer has not found it very loud, and often the bug must be held to the ear to hear it at all. It resembles somewhat the hum of a muddauber wasp at its building. Bueno describes it as a "rasping, creaky chirp." This sound or chirping is made by "holding the fore pair of legs in the same plane as the body, perfectly straight" and separated as far as the prothoracic shoulder will permit and then jerking these rigid limbs up and down. The sound-producing device is figured on plate XVIII. There is, on the inner face of the outer lobe of the prothorax surrounding the coxæ, a stridular area as figured. A roughened spot on the coxa makes the rasp that completes the musical device. Kiritshenks in Rev. Russe Entom., X, p. 311, mentions an interesting flight "en masse" of *Ranatra linearis.*

DESCRIPTION OF STAGES.

These are taken from Bueno and relate to *Ranatra quadridentata.*

The Egg.

Size. 3 mm. long; width, 1 mm.; appendages, 5 mm.

Color. White at base, growing dark toward apex; when freshly deposited, clear white.

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* Callibaetis and Blasturus, for instance.

Shape. Imperfectly oval, flattened at the upper end, from which arise two long thread-like processes, longer than the ovum, and thickened at the base, diminishing in thickness toward the apex.

Markings. Surface of chorion thickly covered with irregularly circular pits, in the middle of which is a point. The processes appear smooth.

The writer has photographed an egg (see pl. VII), and adds the following description of them: Length, 2.86 mm.; greatest width, .86 mm. Filaments, basal, amber-colored part 1.35 mm.; the larger, opaque white part, 2.73 mm., the filament measuring a total of 4.1 mm. These filaments are placed at the cephalic end of the egg as shown in the drawing on plate XVIII. The filament is differentiated into two parts, a basal amber-colored part, and an outer, larger opaque white part. The basal part has a core of opaque white and a sheath of amber with the diameter of the cylinder uniform. The outer part is larger than the basal part, and tapers gradually to a point near the tip, where it again enlarges slightly. The tip is acutely rounded.

The surface of the egg is finely but irregularly hexagonally reticulate, appearing punctate under low power. Surface is rough. Color is cream, at first light, darkening with age. Micropylar spot near filaments as shown in drawing. Clear, smooth and amber colored. The central spot very dark. This spot can be seen to be reticulate under certain lighting as can also the white part of the filaments. Here the reticulation is very fine.

First Instar.

"Form in a general way resembles the adult. It is, however, broader in proportion to length. The head, including the eyes, is broader than long, excluding the rostrum. Each eye is less than one-third the width of the head, round and projecting beyond the thoracic margins. The thorax is a little under one-third the total length of the bug. It shows the three rings.

"The rostrum is four-jointed, stout, the first joint stoutest, about twice as long as the second, and subequal to the third and fourth. The fourth or terminal joint is furnished with tactile hairs, as in the adult, the antennæ are short, club-shaped, one-jointed, the extremity nearly as broad as the length, situated near the basal joint of the rostrum. The thorax is a little under one-third the total length of the bug, and shows the three rings. The bifid air-tube is absent, its place being taken by the blunt extension of the terminal abdominal segment, as described in connection with the respiratory system. The legs are comparatively stout, the second and third pairs being nearly as long as the entire bug. The tarsi of the first pair are one-jointed and entirely destitute of claws; those of the second and third pair are also one-jointed, armed with long claws. The tibiæ of these two pairs are armed with a comb-like row of stout spines going partly around at the distal end, at the tarsal joint, and are furnished with a few coarse hairs at this end also. The first pair of pedes is the counterpart of those of the adult, except that they are much broader in proportion, and do not show the blunt, so-called apical tooth in the femur.

"Size: Long., 8 mm.; lat., 1 mm. at thorax; air-tube long., 1.5 mm.

"Color: Brownish of varying shades, including the legs, which are banded with lighter rings. The eyes are black or dark brown.

"Markings: None sufficiently definite to be called such. There is a lighter median line in the thorax."

Second Instar.

"Form as in the first stage, perhaps a little less broad in proportion to the length. Rostrum as before, except that it is perhaps a little less stout. Antennæ still blunt, short and stout, but not so club-shaped. They now begin to show two equal joints. The legs as before, the first pair not quite so broad proportionally, with the blunt apical femoral tooth beginning to show as an undulation in the inner side of the femur. The tibiæ of the second and third pair are better provided with spines, which increase in number distally. The terminal combs very apparent.

"Size: Long., 13 mm.; lat. not measured, dimensions being taken from moulted skins.

"Air-tube, 2.7 mm."

Third Instar.

"Form. not greatly changed from the preceding instars. except for slight variations in proportions.

"Rostrum, much as before, but a little slimmer. In this instar the tactile hairs at the extremity of the proboscis are quite noticeable.

"Antennæ appear imperfectly three-jointed in this instar. The suture separating the basal joint is quite noticeable, and that between the second and third joints shows as an incision in the outer margin of the antennæ. from which a little impressed line goes about half way across. Below and above this indentation are two prominences, the beginning of the lobes of the segments. Both prominences are armed with a stout spine. that of the third joint being about twice as thick as that of the second. The third joint appears to be pitted at the rounded end.

"Thorax much narrower. distinctly trisegmentate. Head closer to the adult shape, the eyes flattened on the inner side. and quite prominent. The wing-pads first appear in this instar, though very small and rudimentary.

"Legs and tarsi as before. with the spines of the second and third pair of tibiæ stronger, and the tibial comb more developed. In this instar the fringing hairs of the second and third appear. scattered on the femora and sparse on the tibiæ, but quite long.

"The false stigmata are quite noticeable at the sides of the abdomen. as darkened spots in the integument. The legs are now shorter than the length of the bug, and reach but little beyond the extremity of the respiratory tube. The first pair are not quite as broad proportionally as in the previous instars. and show the same undulations of the femora where the second tooth will be.

"Size: Long. (extremity of the rostrum to end of siphon). 19 mm.; lat., 1.4 mm.; air-tube, long., 4 mm."

Fourth Instar.

"Form as before. Rostrum but slightly changed.

"Antennæ evidently three-jointed, the prominences more developed, and the several spines on the third and second segments quite evident.

"Legs and tarsi as before, with the peculiarities more accentuated. They extend only a litle beyond the siphon, and are therefore not as long as the body by the length of the thorax.

"Colour more or less mottled, with banded legs. General tint grayish.

"Size: Long., 30 mm.; lat. (not taken, specimen being only a cast skin in this instar); air-tube, long., 7 mm."

Fifth Instar.

"Form elongate as in the adult. Head, including eyes and exclusive of rostrum, broader than long. Rostrum as before, but nearer the adult shape. The second joint begins to show the basal constriction so notable in the adult.

"The rostrum is shorter than the length of the head. Eyes trans-

versely elongate, somewhat flattened on the inner margin, projecting beyond the expanded anterior portion of the prothorax. Antennæ are still two-jointed, the basal joint extending into a process, nearly as stout as the terminal joint, and about three-fifths as long. The suture between the joints is very faint. The joints are now abundantly furnished with the tactile spines, which reach full development in the adult. Prothorax widened anteriorly by the sockets of the anterior pedes, gradually constricted towards middle, and expanding again basally, but not quite as broad as the anterior portion; excavate for the insertion of the head and truncate posteriorly. Prosternum not sulcate, deeply excavate posteriorly. Mesothorax with long narrow wing-pads of the hemelytra, pointed posteriorly in the middle. Metathorax concealed. First abdominal segment showing as a ring between the wing-pads of the posterior alæ, which barely attain the extremity of the pads of the hemelytra. A straight suture marks off this segment from the next. The abdomen is more than twice the length of the thorax, the segment following the thorax slightly constricted. The sides of the abdomen are folded over itself, and are furnished with fringing hairs. There is an indentation in the edge at each segment that bears the thickening of the formative pseudo-stigmata. The abdomen has only six apparent segments and the siphon or air-tube. The false stigmata show in segments three to five, dorsally, as thickenings of the integument, darker than the surrounding skin. The siphon is jointed to the sixth segment, and freely movable. The abdomen is keeled beneath, the keel bearing a fringe of short hairs on each side, which meet those of the inflexed abdominal margin. The legs approach more closely to the adult. The second so-called tooth or prominence in the first pair is quite evident. The true tooth is large and triangular, and the clawless tarsus rests against it when the tibia is folded on the femur. The second and third pair are slender, ciliate, with globose coxæ; the tarsus of the second pair does not quite reach and the second goes slightly beyond the end of the siphon. Both these are one-jointed, and armed with prominent curved double claws.

"Size: Long., 44.4 mm. (from tip of rostrum to tip of siphon); lat., 2.9 mm. (at the thorax, but *not* at wing-pads). Siphon, long., 12.3 mm.

"Colour: More or less luteous of varying degrees, without any special pattern. The legs, which in the preceding instars are banded, are apparently unicolorus in this. This, however, may be the peculiarity of the two individuals from which this description has been drawn up. The eyes are black and shining."

Family NOTONECTIDÆ Leach 1815.

Leach, Brewster's Edinbg. Encyc., IX, p. 124.

A. Taxonomy of Notonectidæ.

Family Characteristics. Perfectly aquatic forms, differing from all others in the persistent habit of swimming on their backs. They are much deeper bodied than other Heteroptera which live in the water, and while being oval in form with the apex of the wing-covers conical, have the convexity of the surface above. Their eyes are large, reniform, twice sinuated on the outer side, and project a little way over the front margin of the prothorax. Ocelli are absent. Antennæ 4-segmented, shorter than the head and partly concealed in depressions between the head and thorax. Rostrum 3- or 4-segmented. Hind limbs fringed for swimming (sometimes not conspicuous in museum specimens of Plea.) Tarsi 2-segmented (male of Anisops has one segmented tarsi on front limb.) Two tarsal claws present in all, but inconspicuous in the hind limbs of

those with well-developed swimming fringes. Pronotum is transverse, moderately convex, and narrower in front than behind. The venter of the abdomen is equipped with a median longitudinal keel or carina and provided along the lateral margins with guard hairs for closing over the two longitudinal troughs, thus forming air channels.—*From Uhler and Parshley.*

The family Notonectidæ embraces, according to Kirkaldy, two subfamilies: Pleinæ and Notonectinæ. In his "Revision of the Notonectidæ, Part I," in Trans. Ent. Soc. London (3), vol. 35, p. 393-426, 1897, this author begins his systematic revision of the family. This is continued in a second paper which appeared in the "Wiener Entomologischen Zeitung" for 1904, and entitled "Uber Notonectiden."

In the following year Bueno published "The genus Notonecta in America North of Mexico."

Kirkaldy lists six genera in the subfamily Notonectinæ: *Notonecta* L. *Anisops* Spin., *Enithares* Spin., *Martarega* B. White, and *Nychia* Stal. It is in his second paper that he erects the genus *Buenoa* which is allied to *Anisops.* In this country we have the three genera: *Notonecta, Buenoa* and *Plea.* These may be separated by the following:

KEY TO GENERA.

A. Legs are quite similar. *Plea* Leach.

AA. Legs dissimilar, hind legs flattened and fringed for swimming.

B. Last segment of antennæ much shorter than the penultimate. *Notonecta* Linn.

BB. Last segment of antennæ longer than the penultimate. *Buenoa* Kirk.

Of these three genera *Notonecta* is the commonest, being represented in this country by 12 species, the genus *Buenoa* comes next with 5, while the little *Plea* so far is credited in the literature with but one.

Genus PLEA Leach.

DESCRIPTION OF GENUS.

"The thorax is obscurely hexagonal, with the hinder margin prominent and rounded; the head as broad as the broadest part of the thorax; the eyes are rather oblong, without the least tendency to converge behind; the hinder pair of legs not more ciliated* than the others, but are terminated by very strong and distinct claws; the tips of the elytra accuminated and entire."—*Leach.*

One species so far listed for the United States, which is *Plea striola* Fieber. Kirkaldy, 1904, remarks: "Wahrscheinlich haben Uhler und champion zwei oder drei arten hier vermischt." An examination of the material in various collections would suggest that we may have more than one species. Kirkaldy lists two genera in the subfamily *Pleinæ*—*Plea* and *Helotrephes.* To the first he ascribed 12 species, and to the latter, 4 species. It is interesting to note that he considers the *Plea minutissima* of Leach and of Fieber under *P leachi* McGregor and Kirkaldy.

* They are more ciliated in our own species.

Plea striola Fieber, 1844.

"Highly arched behind; wing covers pointed; forehead with brownish-red median stripe; eyes black; hind half of closing suture brown. From North America.

"It is three-fourths lines long. Similar to the two preceding species, but noticeably narrowed and pointed behind. Grayish yellow. Over the front, a brownish-red median stripe. Eyes black. The entire dorsal surface is unflecked. The wing covers behind the suture are much higher arched than the other species. Posterior half of suture brown, darker at the margins. Legs yellowish, last tarsal segment brown at the tip. Femur dark brown at base. The sculpturing consists of an impressed point in the middle of the five or six covered reticulations clearly visible in the substance of the wing cover, a very short delicate seta arises from each puncture, which is visible only on close observation."—*Fieber in Entomologische Monographien,* 1844, pp. 18-19.

Genus NOTONECTA L.

"*Head.* Eyes not contiguous. Labrum attaining to about the middle of the second rostral segment. Last segment of antenna shorter than penultimate.

"*Thorax.* Pronotum not very transverse. Alæ present. Hemelytra divided into clavus, corium and membrane. Scutellum large and almost equal in length to the metanotum, except in *N. mexicana,* where it is only about half its length. Hind femora not attaining to the apex of hemelytra. Posterior ambulacra practically contiguous. Intermediate ambulcara not nearly contiguous.

"*Abdomen.* Median ventral carina of the abdomen is thickly pilose, as are the lateral margins, thus forming a waterproof covered way over the 'gutters' which lie, one on each side of the carina, for the conveyance of air. The junctures of the connexival ventral segments are always covered with short thick hair, and the scutellum and hemelytra are generally clothed with short golden yellow pubescence. The sexes are almost indistinguishable in size, form, colour and general appearance, though, of course, the female, when full of mature ova, is dilated more than at other times. They can be readily separated by an examination of the last three or four abdominal ventral segments. These are horizontal in the female, rounded and anteriorly excavated in the male."

Specific characters suitable for diagnosis are difficult to find. Kirkaldy used head measurements. These were also employed by Bueno and are used in the following tables. Color does not furnish a reliable diagnostic character. Kirkaldy, in casting about for some specific characters, said:

"Great hopes were entertained by me that the male genitalia would furnish a reliable diagnostic character, but in the few species (*N. glauca, N. lutea, N. irrorata* and *N undulata*), of which suitable material was available, these hopes have not been realized."

The writer has examined the ovipositors of the females of most of the species in America and finds considerable specific difference in some. He is quite sure he could distinguish any one of the four species above mentioned from one of the gonapophyses of the female, alone. Whether Dr. Kirkaldy studied them with the same care and discrimination that Dr. Harry Knight has used with the Miridæ remains to be seen.

KEY TO GENUS NOTONECTA LINN.

Rearranged from Bueno's Notonecta of North America, 1905.

A. Small species, subrobust.

B. Vertex* twice or less than twice the synthlipsis.†

C. Vertex 1½ to 2 times the synthlipsis; width of pronotum 1¾ times length; width of scutellum 1½ times the length; length of insect 9.4 mm. to 11 mm. *N. indica.*

CC. Vertex 2 times synthlipsis; width of pronotum 1⅘ times its length; width of scutellum 1⅕ times its length; length of insect 10.2 mm. *N. howardii.*

BB. Vertex more than twice the synthlipsis; vertex 2½ times synthlipsis; width of pronotum 2 times its length; width of scutellum 1⅕ times its length; length of insect 10 mm. to 13 mm. *N. undulata.*

AA. Small, slender species.

B. Vertex 3 times synthlipsis; width of pronotum 2 times its length; width of scutellum 1⅓ times its length; length of insect 8.2 mm. to 10.2 mm. *N. variabilis.*

BB. Vertex more than 3 times synthlipsis.

C. Vertex 6 times synthlipsis; width of pronotum 1⅔ times the length; width of scutellum 1¼ times the length; length of insect 8 mm. to 8.8 mm. *N. raleighi.*

CC. Vertex 6 to 8 times synthlipsis; width of pronotum 1⅘ times its length; width of scutellum 1⅙ times its length; length of insect 10.7 mm to 12 mm. *N. uhleri.*

AAA. Medium sized, robust species.

B. Vertex at least 3 times synthlipsis.

C. Vertex 3 to 4½ times synthlipsis; width of pronotum 2½ times its length; width of scutellum 1½ times its length; length of insect 11 mm. to 14 mm. *N. mexicana.*

CC. Vertex 3 times synthlipsis; width of pronotum 2 times the length; width of scutellum 1¼ times its length; length of insect 12.1 mm. to 14.4 mm. *N. irrorata.*

BB. Vertex less than 3 times the synthlipsis.

C. Vertex 2 to 2½ times the synthlipsis; width of pronotum 2 times its length; width of scutellum 1⅕ times its length; length of insect 12.1 mm. to 17 mm. *N. lutea.*

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* Vertex—distance between the eyes at the front.

† Synthlipsis—distance between the eyes at base of the head, at the most constricted part.

AAA. Medium sized, robust species—*concluded.*

CC. Vertex 2½ times synthlipsis; width of pronotum 1⅐ times its length; width of scutellum 1⅕ times its length; length of insect 13.1 mm. to 14 mm. *N. montezuma.*

BBB. Vertex not twice as wide as synthlipsis.

C. Vertex 1⅓ times synthlipsis; width of pronotum 1⅔ times its length; width of scutellum 1⅓ times its length; length of insect 8 mm. to 13 mm. *N. shooterii.*

CC. Vertex but slightly wider than synthlipsis; width of pronotum 2 times its length; width of scutellum 1⅕ times its length; length of insect 12.6 mm. to 15.5 mm. *N. insulata.*

The following descriptions have been copied from Bueno, 1905. He used Kirkaldy's copy of descriptions, which appeared in his Revision of the Notonectidæ, pt. 1, Trans. Ent. Soc. London, 1897, and added measurements, etc. I therefore credit them "Bueno and Kirkaldy."

Notonecta indica Linne 1771.

Linne, "Mantissa Plantorum," p. 534.

"Head rather large, notocephalic lateral margins straight, not very divergent from the base; vertex varying from one and one half to twice as wide as synthlipsis. Scutellum rather shorter than in *N. undulata* Say. Hemelytra variable: (1) fulvous or dark stramineous, with a broad black fascia near the apex, occupying the basal two thirds of the membrane and the apex of the corium; (2) varying from bluish black to violet brown, the corial margins of the clavus and a broad irregular blotch about the middle of the corium, fulvous or dark stramineous. Otherwise like *N. undulata* Say.

"Long., 9.4 to 11 mm.; lat., 3.4 to 3.6 mm.—*Bueno and Kirkaldy.*

Distribution: Utah, Nevada, California, Arizona, Oregon and Texas. Bueno says that this bug is extremely abundant in Lake Texcoco, Mexico, where its ova, together with those of one or two Corixas, are used as food under the name "huantle."

Notonecta howardii Buneo 1905.

Bueno, Journ. N. Y. Ent. Soc., vol. 13, p. 151.

"Notocephalic lateral margins of head curved; vertex twice as wide as synthlipsis; base of eyes about twice as wide as synthlipsis. Pronotum four-fifths broader than long, humeral and lateral margins sinuate. Scutellum one-fifth longer than wide, not concolorous. Hemelytra clouded with black going into smoky, and with a broad black band across the membrane and the apex of the corium. Apex of the membrane smoky. Corium and clavus moderately clothed with a golden pubescence. Membrane lobes subequal. Pedes: Intermediate femoral spur small, rather blunt, concolorous.

"Measurements: Vertex, 1 mm.; snythlipsis, 0.5 mm.; pronotum, lat., 3.5 mm., long., 1.9 mm.; scutellum, lat., 2.7 to 2.9 mm., long., 2.2 to 2.4 mm.; insect, long., 10.2 mm., lat. (pron.), 3.5 mm.; types, No. —, U. S. N. M.

"Described from two specimens in the U. S. National Museum, collected by Dr. E. A. Mearns in Arizona."—*Bueno and Kirkaldy.*

Notonecta undulata Say 1832.

Say, Disc. n. sp. Het. Hem. N. A. Fitch reprint, p. 812. Le Conte Ed. Comple. Writ. 1859, p. 368, vol. 1.

"Head diverging curvedly (varying in degree) from the synthlipsis, which is not quite two and a half times less wide than the vertex. Pronotum very similar to that of *N. glauca Linne*, but the humeral margins as a rule not distinct. Scutellum not quite one-fourth shorter than the metanotum, varying in color from pale luteous to black, with divers intermediate arrangements of the two colors; similar hemelytrical markings occurring with dissimilarly colored scutella and vice versa. Metanotum varying from luteous to black, with three or more dark castaneous stripes; scutellar margin luteous. Hemelytra exceedingly variable, giving rise to a number of well-marked varieties, though these are linked together by intermediate forms.—*Bueno and Kirkaldy.*

Distribution: General over United States—Kansas; Colorado; Missouri; Nebraska; Massachusetts; Rhode Island; New York; New Jersey; Maryland; Washington, D. C.; Quebec, Canada; Illinois; Texas; Arizona; Idaho; Virginia; Iowa; Ohio; Tennessee; Indiana; Kentucky; Utah; Ontario; Maine; North Carolina; Florida; Louisiana; Minnesota; Montana; New Mexico; California; Oregon; British Columbia; Vancouver Island; Manitoba; New Hampshire; Vermont and Connecticut.

Notonecta variabilis Fieber 1851.

Abh. Bohm. Ges. Wiss. (5), VII, p. 477 (in part).

"Head, notocephalic lateral margins diverging curvedly from the narrow base, vertex about three times as wide as synthlipsis. Pronotum, width of posterior margin not quite twice as great as the length of the pronotum. Hemelytra, clear white inclining to yellowish, with a golden pubescence. Alar nervures pale golden yellow. Pedes and abdomen as in *N. undulata* Say.

"Long., 8.2 to 10.2 mm.; lat., 3.2 to 3.7 mm."—*Bueno and Kirkaldy.*

Distribution: Kansas, Nebraska, Ohio, Michigan, Wisconsin, Rhode Island, Indiana, Maryland, Pennsylvania, Massachusetts, Illinois, New York, Quebec, Ontario, Maine, New Jersey, District of Columbia, North Carolina, Florida, Ohio, New Hampshire, Vermont and Connecticut.

Notonecta raleighi Bueno 1907.

Bueno, Can. Ent., vol. 39, p. 225.

"Head: Notocephalic lateral margins nearly straight; vertex more than six times as wide as synthlipsis; base of eyes over four times as wide as synthlipsis.

"Pronotum two-thirds broader than long; base and lateral margins nearly straight, humeral margin sinuate. Scutellum one-quarter broader than long, sides pronouncedly sinuate, caudal angle long. Hemelytra little longer than the body, moderately clothed with a silvery pubescence on the clavus and corium; membrane lobes unequal. Abdomen luteous, fringing ciliæ black, sparse. Pedes luteous; intermediate femoral spur concolorous, long, thin and sharp.

"Coloration: Eyes dark reddish-brown. Cranium and prothorax whitish. Scutellum ranges from pure light yellowish to black, disk margined with smoky orange-yellow on the hemelytral margins. Hemelytra ranging from white with vague beginnings of the corial fasciæ and black humeri with white membrane, through all intergrades to a form with a blackish stripe along the anterior margin of the corium; black margins to the clavus along the scutellar edges; a blackish streak along the corium near to and parallel to the claval suture; black corial fasciæ

merging into the black membrane, which shades off into smoky and then white at the apex. One of the types is the most pronouncedly melanic specimen of the species in a series of 60 or so specimens. In this the extreme of scutellar darkness with orange-red edges obtains. The external edges of the clavus are broadly black, shading into smoky to the corial suture; the dark band on the corium parallel to this suture is broad; the humerus has a black streak running into the corium, which is dark luteous, except for the black fasciæ which coalesce with the black membrane, which in turn lightens to smoky at the apex. The structural characters are the same as in the others.

"Measurements. Vertex, 1 mm.; synthlipsis, 0.15 mm.; pronotum, long., 1.5 mm to 1.8 mm.; pronotum, lat. (at humeral angle), 2.5 mm. to 2.9 mm. (at base 2 mm.); scutellum, long., 1.6 mm.; scutellum, lat., 2 mm.; insect., long., 8 mm. to 8.8 mm.; insect, lat. (at humeral angle of pronotum), 2.5 to 2.9 mm.

"Described from sixteen specimens from Raleigh, N. C. Types: Collections U. S. National Museum, American Museum of Natural History, C. S. Brimley, and mine.

"This species very much resembles a dwarf *variabilis*, but it is easily distinguishable by the cephalic structure."—*Bueno.*

Distribution: Bueno gives it as locally abundant at Raleigh, N. C. He records it also from New Jersey, Illinois, Maryland and Washington, D. C.

Notonecta uhleri Kirk. 1897.

Kirkaldy, Ann. Mag. Nat. Hist., (6), XX, p. 58.

"Head: Notocephalon in the form of an inverted wine decanter, margins greatly curved, widely diverging toward the vertex, which is six to eight times wider than the synthlipsis, at which point the eyes are almost contiguous; breadth of the eye about ten times as great as that of the synthlipsis. Pronotum: humeral angles acute, accentuated lateral margins sinuate, humeral margins little separate from the posterior margin. Metanotum dark purple-brown. Hemelytra varying from dark brick-red to rich orange-yellow; a large irregular black blotch at the base of the corium extending transversely and nonacuminately from the apex of the clavus to the golden-yellow exocorial lateral submargin; membrane dark red-brown, apically black—this tint encroaching more or less basally. Alar nervures brown. Pedes: Coxæ blackish; intermediate tibial spur blunt, subcylindrical. Abdominis dorsum: first and second segments rufotestaceous, deeper marginally, the remainder flavotestaceous, lurid marginally; this latter tint encroaching more and more apically. Abdominis venter rufotestaceous, densely provided with greenish-black cilia." —*Bueno and Kirkaldy.*

Distribution: New York, Massachusetts, Florida, New Jersey, Louisiana, and District of Columbia.

This is a rare bug according to Bueno and the writer feels proud to have one specimen in his own collection—the gift of Mr. Bueno.

Notonecta mexicana Amyot and Serville 1843.

Amyot et Serville, Hist. Nat. Ins. Hem., p. 453, pl. 8, fig. 7.

"Head narrow at base, parallel for a short space, then sinuately diverging; vertex from three and one-half to four and a half times as wide as synthlipsis. Pronotum very transverse, about two and one-half times wider than long, lateral margins slightly sinuate, humeral margins gently and elongately curved, posterior margin not sinuate; humeral angles acute, accentuated. Metanotum not quite half as long again as scutellum, black (dark vars.) or violet brown margined luteous (pale vars.) Hemelytra varying in color, membrane lobes subequal. Alæ

semi-transparent, smoky, nervures brown (pale vars.), or semitransparent, smoky black, nervures blackish-brown (dark vars.). Abdominis dorsum black (dark vars.), or rufoluteous with paler genital segments (pale vars.). Abdominis venter varying from black to testaceous.

"Long., 11 to 14 mm.; lat., 4.5 to 4.8 mm."—*Bueno and Kirkaldy.*

Bueno adds:

"The shape of the head and the very transverse pronotum separate it very readily from the other species of the genus. In his revision, Kirkaldy goes at length into the color variations, and since his remarks cover the ground exactly, I reproduce them here: 'The hemelytra are usually rich scarlet, with black membrane, but the latter hue often extends beyond the apical margins of the clavus and corium; the scarlet also varies much in shade, graduating in one direction to pale greenish-white through pale yellow, pale olive-green, deep yellow, orange, and pinkish, and in the other through crimson and violet-red to deep violet-black, though in the last the sutures of the hemelytral divisions are usually narrowly violet-red; in some specimens the apex of the corium is black, from the base of the membrane to the margins of the hemelytra in a straight line, and the rest of the hemelytra are rich crimson. The hemelytra are rarely maculate, occasionally the center of the clavocorial suture has a more or less pronounced black smudge about the center. It may be convenient to propose the varietal names *ceres* for the pale-colored forms and *hades* for the southern violet-black race. Herrich-Schaffer notes a variety with a large central ochreous stripe on the scutellum, while Fieber describes among the varieties with red hemelytra: (1) *Schild schmutziggelb mit braunen grund,* and (2) *Schild braun mit gelblichem rand'*—these three varieties I have not seen. In the U. S. National Museum and Heidemann collections the specimens from Colorado Canon, Hot Springs and Catalina Mountains, Arizona, are var. *hades,* and above the average size and with more prominent eyes. In the National Museum there is a specimen from Mexico which has the scutellum with the yellowish base (or apex) mentioned by Fieber."

Localities: Colorado, Arizona, California. Uhler gives its distribution as "western states."

Notonecta irrorata Uhler 1876.

"Head small, notocephalic lateral margins diverging widely, vertex a little more than three times as wide as the synthlipsis; width of vertex and of the eye subequal; eyes rather larger proportionally than in *N. triguttata*, etc. Pronotum much wider basally than apically, lateral margins not sinuate, humeral angles acute, humeral and posterior margins sinuate. Hemelytra rich black, irrorated (especially on the clavus) with refulgent yellow brown, anterior lobe of membrane and apex of exterior lobe smoky. The irrorations vary greatly in different individuals; in some the corium and membrane are almost immaculate, in others the whole of the clavus and corium is irrorated, imparting a checkered appearance, while in others the clavus is rich (almost metallic) yellow-brown with faint, distant, narrow black lines. Alar nervures brown. Pedes: intermediate tibial spur small. Abdominsis dorsum: first to fifth segments black, sixth, seventh and eighth sordid grayish-brown. Abdominis venter black.

"Long., 11.8 mm. to 14.4; lat., 3.6 to 4.7 mm."—*Bueno and Kirkaldy.*

Localities: Illinois; Kentucky; Ohio; Tennessee; Montana; Quebec; Maryland; New York; Washington, D. C.; Rhode Island; Indiana; New Jersey; Ontario; Maine, Massachusetts; Michigan; Florida; New Hampshire; and Connecticut.

Notonecta lutea Muller 1776.

O. F. Muller, Zoölogia Danise Prodromus, 1776.

"Head large, notocephalic lateral margins slightly diverging from the base, vertex two to two and a quarter times as wide as synthlipsis. Entirely luteous (except the dark claret eyes, occasional dark-brown markings along the sutures of the clavus, etc., the bronze-brown sternal hair-tufts, the black unguiculi and venter). Scutellum a third wider than long. Exterior lobe of membrane about half the size of the interior lobe and obviously not so long. Alar nervures luteous. Pedes; spine on intermediate tibia large, acute, black-tipped.

"Long., 13 to 17.1 mm.; lat., 4.5 to 5.5 mm."—*Bueno and Kirkaldy.*

Localities: Bearfoot Mountains, B. C., North America. This is a Palearctic species noted for the first time in this country by Bueno in the *Ent. News* for June, 1904. Its former range in Europe is given as Lapland, Finland, where it is general but rare, Sweden, Bohemia and Austria. In Asia it is recorded for Siberia.

Notonecta shooterii Uhler 1894.

Uhlér, Proc. Calif. Acad. Sci., 2d ser., vol. 4, p. 292.

"Head short, notocephalic lateral margins slightly diverging from the base and slightly converging towards the vertex, which is about one-third larger than the synthlipsis. Pronotum large, rather longer in proportion to its width than in the other species, lateral and humeral margins sinuate. Scutellum small, nearly one-third shorter than the metanotum; black, base purple-brown. Sterna dull ivory-white, corium more or less concolorous, forming with the clavus a blotch of varying extent, and usually with a whitish spot along the apical margin, the claval and corial markings very similarly disposed to those of *N. triguttata;* apex of membrane, smoky. The hemelytra vary, however, very much, being quite violet black in some individuals (*melæna,* var. nov.), while in others they are concolorous pale luteous. Membrane lobes always subequal in ordinary forms; generally unequal in the leucochroic varieties (*ochrothœ,* var. nov.), and rarely subequal (*tearca,* var. nov.). Alar nervures rich brown. Pedes: intermediate coxæ black, tibial spur small, rather blunt. Abdominis dorsum: segments 1 black, 2-5 violet-brown (the fifth apically black), 6 blackish, genital segments greenish-testaceous, all the segments more or less dull blackish laterally. Venter varying from green to black, carina and cilia black."

"Long., 8 to 13 mm.; lat. pron., 4 to 4.7 mm."—*Bueno and Kirkaldy.*

Localities: California, Mexico and Central America.

Notonecta montezuma Kirkaldy 1897.

Kirkaldy, Tr. Ent. Soc. London, 1897, p. 402.

"Head narrow at base, similar to that of *N. mexicana,* notocephalic lateral margins fairly straight, diverging from the base, vertex two and a half to three times as wide as synthlipsis. Hemelytra orange-red, suffused (especially marginally) with crimson, and sparingly and irregularly marked with black; membrane bluish-black, apex brownish-black, lobes subequal. Pedes: coxæ brownish-black, intermediate tibial spur, small, rather blunt. Abdominis dorsum: segment 1 black, 2 sordid testaceous, suffused with crimson and margin with black. Venter black.

"Long., 13.1 to 14 mm.; lat., 4.7 to 5 mm."—*Bueno and Kirkaldy.*

Localities: California, Mexico. A rare species, only two specimens in collections, according to Bueno. The type is from Mexico.

Notonecta insulata Kirby 1837.

W. Kirby in Richardson's Fauna Boreali Americana Insects (Reprint in Can. Ent. 1878).

"Head; notocephalic lateral margins fairly straight and nearly parallel, very slightly constricted near the base; vertex little wider than synthlipsis, which is about one-fourth less than the width of the base of the eye. Lateral and humeral margins of the pronotum sinuate. Scutellum varying slightly in length, but occasionally reaching and usually nearly reaching the base of the metanotum, black (Fieber in *N. rugosa* records two varieties (*coridgera* and *basalis*) with yellowish scutellum, but I have not seen them). Hemelytra variable in pattern and color . . . Alæ, basal nervures crimson, the others yellow-brown. Pedes: coxæ black, intermediate tibial spur small, slender, not tipped with black. Abdominis dorsum: segments 1 black, 2-6 brilliant scarlet, 7-8 reddish-testaceous. Abdominis venter black, connexivum and central carina green.

"Long., 12.6 to 15.5 mm.; lat., 4.8 to 5.6 mm."—*Bueno and Kirkaldy.*

Localities: Nebraska, Colorado, Arizona, New Mexico, New Jersey, Nevada, Connecticut, Indiana, Utah, Maine, Oregon, California, Quebec, Ontario, Massachusetts, New York, Montana, Dakota, Idaho, Vancouver Island, New Hampshire and Rhode Island.

Genus BUENOA Kirkaldy.

Named in honor of Mr. J. T. de la Torre Bueno.

Similar to the genus *Anisops*, but the male is provided with two tarsal segments on the front legs, and the claws are differently formed.

Head: Eyes not contiguous, but interior margins about parallel, their margins curving slightly, making distance at vertex greatest, and interocular space long and narrow. Labrum reaching to apex of second rostral segment; last segment of antenna longer than the penultimate.

Thorax: Pronotum not most transverse; alæ present and the hemelytra divided into clavus, corium and membrane, and more transparent and hyaline than in *Notonecta*. Hind femora not reaching apex of hemelytra. The hind tarsi are provided with more conspicuous claws than *Notonecta*. The middle and front legs are armed with long spines and the males of *Buenoa elegans* and *Buenoa margaritacea* at least are equipped on the front leg with a tibial structure borne on the inner face of a prominence, which is forced into a thin elongate spur by the elevation of the inner angle or margin of the tibia near its base. Tarsi of front legs 2-segmented in both sexes.

Abdomen: The abdomen is provided with a median ventral carina and the lateral margins of the venter are provided with guard hairs which cover the "gutters." The female has the last ventral abdominal segments modified for sheathing the ovipositor, which consists in the main of a pair of somewhat spatulate chitinized gonapophyses for placing the eggs in the tissues of plants.

KEY TO THE SPECIES OF GENUS BUENOA.

A. Species over 6 mm. long.

  B. Pronotum in the male with four depressions, appearing tricarinate in this sex.

A. Species over 6 mm. long—*concluded.*

C. Head, including the large eyes, nearly as wide as the pronotum in the male, a little narrower in the female. Body robust; legs stout, interocular space not very narrow behind. Length, 7.5 to 9 mm.
B. carinata Champ.

CC. Head, including the large, somewhat flattened eyes, distinctly narrower than the pronotum in both sexes; legs rather slender, and, like the greater part of the body, pale in color. Length, 6.5 mm. *B. albida* Champ.

BB. Pronotum almost unimpressed, though lateral carinæ are well marked in some males. Length, 6.7-8.1 mm.
B. margaritacea Bueno.

AA. Species less than 6 mm. long.

B. Eyes large and prominent; shape slender.
B. platycnemis Fieb.

BB. Eyes large, but not prominent; shape more convex.
B. elegans Fieb.

The above table is adapted from Champion and from Bueno to separate the species given in Van Duzee. Kirkaldy evidently did not recognize either of Champion's species, for he says of *B. albida* Champ. "Wahrscheinlich mit *A. platycnemis* identisch" and *A. carinatus* Champ. he makes a synonym of his own *B. antigone.* The writer has been interested in providing a means of determining the bugs which he may meet in his biological studies. He feels that such guides should have been provided by those best acquainted with the groups, but where no keys are available he has improvised them from the literature and such material as has been authoritatively identified for him by such workers as Bueno, Barber, Gibson, Parshley, etc. If the keys include synonyms and false statements the reader is referred to Van Duzee's Catalogue and to the descriptive literature. The writer wishes most heartily that there were more papers dealing with the taxonomy of the aquatics, such as those of Uhler, of Bueno, and of Barber.

Buenoa carinata Champion. 1901.

Biologia Centrali Americana, vol. 2, p. 372, 1901.

"Elongate, robust, smooth, shining; head and pronotum sordid white. the color of the latter modified by that of the mesonotum showing through; the scutellum usually black in front and rufo-testaceous or testaceous behind, sometimes entirely pale; the elytra sordid white, the colour modified by that of the metanotum and the apex of the abdomen showing through, these parts being usually black and the rest of the upper surface rufo-testaceous or testaceous; the under surface, antennæ, and legs testaceous, the venter black, the terminal segment and some spots on the connexivum excepted, the posterior femora beneath, and sometimes the anterior and intermediate tibiæ externally, each with a dark streak down the middle. Head (with the large eyes) nearly as wide as the pronotum in the male, a little narrower in the female; interocular space not quite twice as wide on the vertex as at the base, considerably narrowed beneath, the vertex sulcate down the middle. Pronotum about as long as the scutellum in the male, slightly shorter

in the female; the disc in the male with two broad elongate depressions towards the middle and a very large subtriangular depression on each side, these latter almost enclosing an oblique oval elevation behind; the spaces between the depressions appearing raised and forming three longitudinal ridges. Legs stout, the four anterior tibiæ much widened, the anterior pair in the male angularly dilated on the lower edge at the base beneath, and also wider than in the female.

"Length 7.5 to 9; breadth 2.25 to 2.5 mm."

Localities: Florida, New Mexico and California.

Buenoa albida Champion 1901.

Biologia Centrali Americana, vol. 2, p. 373, 1901.

"Elongate, narrow, rather slender, smooth, shining; sordid white, the scutellum more or less rufo-testaceous, the legs, antennæ, and under surface pale testaceous; the abdomen above testaceous, with transverse black bands, beneath black, with the median carina and some marks on the connexival segments pale testaceous. Head (with the eyes) narrower than the pronotum in both sexes; interocular space about twice as wide on the vertex as at the base, the vertex sulcate down the middle. Pronotum (along the median line) about as long as the scutellum; the disc in the male with two elongate deep depressions towards the middle and a very large subtriangular shallow depression on each side, thus appearing tricarinate in this sex. Legs rather slender; the anterior tibiæ in the male angularly dilated on the lower edge at the base, and also considerably widened.

"Length 6.5, breadth, 1.875 mm."

Localities: Texas, (Mexico).

Buenoa margaritacea Bueno 1908.

G W. Kirkaldy, in his "Uber Notonectiden," gives a short description in German of a species measuring 6.7 to 8.1 mm. in length and 2 to 2.3 mm. broad, which he says is the commonest North American species. The following is his description of this bug which he considered to be *Buenoa platycnemis* (Fieber) 1852:

"Ventral carina pale. Pronotum of male and female not, or not clearly, carinated. Hind femur with some 100 bristles. Front tibia as long as the tarsus and claws together, first tarsal segment a half longer than the second, this twice as long as the somewhat pointed finger-shaped claw. Middle tibia a little longer than the tarsus, first tarsal segment twice as long as the second, which is double as long as the talon-shaped claws."

Bueno, in Journ. N. Y. Ent. Soc. X, p. 236, also describes this bug under *Anisops platycnemis* but subsequently (1909, Journ. N. Y. Ent. Soc., XVII, pp. 74-77) recognizes it as a new species, to which he gives the name *Buenoa margaritacea*.

Bueno in Jl. N. Y. Ent. Soc., vol. X, gives the following:

"Head rather large, with prominent eyes, notocephalic lateral margins slightly diverging from synthlipsis and again converging toward the vertex; to the naked eye, the notocephalon appears of equal width throughout. Pronotum overlapping base of head somewhat pointedly, and terminating in a point at the meeting of the hemelytra. Metanotum completely covered by the hemelytra. Hemelytra pearly, histrous, varying in color when closed from pure white through a bluish to a blackish tinge; in this respect resembling strongly the shadings of mother-of-pearl. Alar nervures pale; alæ hyaline. Abdominis dorsum, varying

from testaceous base and blackish tip to nearly entirely black. Venter black. Pedes testaceous.

"Length, 6.7 to 8.1 mm.; lat., 2 to 2.3 mm."

Localities: Kansas, New York, New Jersey, Illinois, Florida, Vermont and Massachusetts.

Buenoa platycnemis Fieber 1851.

Rynchotographilla, 1851, p. 61 (described under genus *Anisops*).

"Dirty white. Eyes large. Connexivum narrow, whitish-yellow. Venter black, sides yellowish with three-cornered black median flecks. Hemelytra with black margins (Randrippe.) Scutum black, with margin and tip yellowish. Scutellum ochre-yellowish, brown at base. Mentanotum black. Metanotum ochre-yellowish with brown median stripe. From America, Porto Rico and St. Thomas. Length, 2½ lines. Dirty white. Posterior margin of pronotum above the scutellum scarcely overlapping. The color of the pronotum (Schildes) varies; it is either black, with narrow or broad pale margin, or ochre-yellowish with the base brown. Hind back varies in color, as above mentioned. Dorsal segments blackish brown, next to last and the base of the last, dirty white. Front tibia very broad at base, on one side broadened out into a lobe, in the male a broader tooth toward the base. Front and middle femora on the inside and above, sides of the metathorax, blackish. Appendage of femur with a black spot."—*Fieber.*

Localities: New York, New Jersey, District of Columbia, Illinois, Texas, California.

Buenoa elegans Fieber 1851.

Rhynchotographilen, 1851, pp. 61-62.

"Milky white. Antennæ black. Hemelytra without closing suture (Schlussnath.) Membrane with four-cornered black transverse fleck. Metanotum white. Abdomen black. From America. Length, 2½ lines.

"Head somewhat broader than pronotum, whose posterior margin is gently projecting. Fore edge projecting angularly. Front elongated, truncated and narrowed in front. Labrum longish. Third segment of beak above and fourth entirely black. Margin blackish brown. Hemelytra very finely haired. Breast yellowish. Abdomen black, three basal segments of connexivum with yellowish white posterior margin. Fore tarsi somewhat shorter than the tibiæ, appearing thickened on the inner side at the base with a saffron yellow finely indented wart. Fore and middle tibiæ with a brown median stripe (apparently formed by the dried inner margins of the groove touching.) Margin of parapleura fringed with blackish brown. Foremargin of hind femur brownish transparent. Appendages of femur with a brownish spot. Middle tibia, above on the basal half brownish. Abdomen yellowish. Dorsal segments black, three of these with white median spots at base. Clavus without a trace of a suture fused with the corium. Anus dirty whitish, margin narrowly whitish yellow. Membrane with large, almost elongate, four-cornered blackish-brown opal colored iridescent transverse spot, extending from the outer basal angle to the inner margin."

"Observation: Described by Blanchard and Brulle as *Notonecta nivea* in the Hist. Not. Tom., 3, p. 88, as follows:

"Body of a somewhat moonlight color, short and somewhat convex, head and corselet of a dirty white without spots. Wings white, very transparent, entirely deprived of spots, legs and abdomen of a grayish yellow. Length, 3 to 4 lines."

"It appears that Brulle had two species before him, which do not agree with the above description, but may belong to *A. productus*."

Localities: Maine, New York and New Jersey.

B. Biology of the Notonectidæ.

General Notes. Of all our American water bugs none are more generally known in their native haunts than the back-swimmers. They are to be found in nearly every pool and pond, and afford most interesting objects for aquarium study. The fact that they swim on their backs readily distinguishes them from all other water bugs.

Some of them spend much of their time hanging, back downward, just beneath the surface film, the tip of the abdomen in contact with the surface, the body, head downward, at such an angle that just the claws of the intermediate limbs may touch the surface and the hind limbs directed well forward of right angles to the body poised for a sudden rowing stroke. This, in fact, pictures our best known, and most widely distributed *Notonecta undulata.* Others prefer to float submerged in open water or cling to the shelter and shade of aquatic vegetation.

The predatory tendencies and daring attacks of these insects upon other animals of formidable size have been known from the first biological notes concerning them. Records of the capture of fish and various insects, mature and immature, by members of the genus Notonecta are common. However, the intimate ecological connection of these insects with the life of the pool lies in the fact that a large part of the food of the young of all of them, and the adults of Buenoa and Plea, consists of Ostracods and other small Entomostraca.

The adults of all the species observed in this country pass the winter, either hidden in the mud and other debris of the pool or remain more or less active, as conditions may permit. They have been observed swimming beneath the ice in spring-fed pools in midwinter.

Mating occurs beneath the water in spring, and the females deposit their white oblong-oval eggs, either attaching them by means of a waterproof glue to the surface of sticks and brush in the water, as in the case of most members of the genus Notonecta, or inserting them in the tissues of water plants and the like, as in the case of Plea, Buenoa, and *Notonecta irrorata.*

There are one or more generations, depending upon the species and the climate.

The details of life history and behavior are treated under the notes concerning the various species.

Biological Notes on Plea striola.

Aside from a few notes on habitat, little has been written regarding the biology of our tiny back-swimmer. This little fellow has been taken in tangles of aquatic vegetation, such as Elodea, Chara and the like, in widely separated parts of our country. Van Duzee lists it as occurring in the following states: Kansas, New York, New Jersey, Florida, Illinois, Texas, Iowa, Massachusetts and California.

Even the suggestion concerning its feeding habit which has crept into a recent text on aquatic biology—information taken from a published inference to be sure—is erroneous. The author of the suggestion that Plea apparently subsisted upon the juices of the plants, based it

upon the fact that they were never seen to prey upon the little Crustacea present nor were these forms depleted in numbers appreciably.

The writer has had them under close observation many times and has frequently seen them catch and devour Ostracods and other small Crustacea. The process has been observed under binoculars and differs little from that of any other back-swimmer. The prey is grasped by the fore limbs and the victim rolled about until the stylets locate a vulnerable point. Several small creatures have been captured and destroyed one after another by some Pleas under observation. Their relation, then, to the aquatic complex of life is that of a consumer of small crustacean creatures that abound in the same shelter of the submerged vegetation.

They do spend much time clinging closely to the plant filaments, and when they leave it they go clipping off in a manner indicative of a definite goal. Their locomotion is even and rapid, but the journeys not extended, for they are content, as a rule, to dodge from the shelter of one stem to another. Their hind limbs are not heavily fringed, as is the case with the other genera, and their gait through the water an even scoot, rather than the jerky motion of the others, which use only their hind limbs in strong propelling strokes.*

The writer has read that the hind wings do not exist and that the front ones are united into one.

According to this, their distribution would be restricted to permanent pools to which they had been carried, as adults, attached to transported mats of aquatic vegetation, or perhaps entangled in mud upon the feet of birds or beasts, or as eggs upon or within their supporting plant growth.

However, the writer wonders if a few may not be found which have functional flying wings, for of two specimens placed in a glass tumbler in which the water was one-half inch from the top, one disappeared over night. A study of many specimens shows that the fore wings are not united along the median line. They meet and interlock by a device figured on plate XXV. The hind wings are always represented by distinct pads as shown in the figure on plate XXV. Sometimes these pads are of fair size, and until a very full series has been examined, the writer does not believe it can be said that they may not occasionally possess truly functional wings. A genus of Corixids was once described as having hind wings aborted, but among them the writer has found well-developed flying wings, a point confirmed by Dr. Abbott, who created the genus.

The egg stage has not heretofore been observed. The writer brought in a number of Plea from the field station on July 17, and placed them in an aquarium with Elodea and Chara. Their eggs were inserted in the tissues of the plants as shown on plate XXV. A description of the egg follows:

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* Wefelsheid records a diurnal migration from 2 meters from shore in day time to near the bank in evening.

The Egg.

Size. Length, .598 mm.; diameter, .234 mm.

Color. Very pale greenish.

Shape. Elongate oval, but not regular. Viewed laterally the top line is nearly straight, while the lower line is curved. The anterior pole is flattened on the side bearing the micropyle, which is a slightly curved, cylindrical peg. The surface appears reticulated with irregular hexagons when seen under compound microscope.

Most of our knowledge of these curious little back-swimmers comes from Heinrich Wefelscheid's paper, "Uber die Biologie und Anatomie von *Plea minutissima* Leach," 1912.

This writer made an extended study of the above species. He says it winters as an adult. That the female is larger than the male and that mating begins in May and reaches its height in early June. He figures a mating pair, and states that they may remain in copula as long as two hours. Eggs were found in the laboratory in decaying stems of "*Ranunculus aquatiles.*" They were placed in the stem with the long axis parallel with that of stem, which agrees with our observation on *Plea striola.* Egg stage lasted three or four weeks, and the five larval stages took one and a half months. He says only one generation possible, though Kulgatz says apparently two. As to the life of the adult he remarks: "Die Imago kann mindestens noch ein zweites Mal uber wintern und sich fortpflanzen." He found them preying upon Daphnians, and said they lived a week without food (most any predator will do this), and adds "Sie satzen dann meistens in den Blattescheln oder on den Stenglen und sangten offenbar die Pflanzen safte ein."

In regard to its power to fly, he states "Dennoch scheint es mir nach dem verhältnismässig kräftigen Bau der Flugel nicht sweifelhaft zu sein, dass das Tier, ebenso wie seine nahe verwandte *N. glauca,* noch die Fähigkeit des Fliegens besitzt." He notes also that in the British Museum there is an example from Batavia taken at electric light.

They are capable of making sounds under water and he reports finding "Reibleisten" on the sternum of the mesothorax "mit Hilfe deren das geräusch wohl erzeugt wird," and finds a tympanal organ in the mesothorax, as in Corixa. The remainder of his paper is devoted to many interesting structural studies which he has made. His paper is a doctorate dissertation and shows how much there is to be done with our own species.

Genus NOTONECTA L.

BIOLOGY.

At the close of his "Revision of Notonectidæ, Part I," Kirkaldy stated:

"I had hoped to give an account in this paper of the metamorphoses of *N. glauca* L. Unfortunately my attempts of rearing this species from the ova during two seasons have been only partially successful. I have, however, reared three larval instars from ova deposited in captivity, and am aware of two more, so that *Notonecta* has at least five larval instars.

"In the ultimate and perhaps also the penultimate larval stage, the species can always be determined by the structure of the head; in the first three, however, the shape of the head and eyes does not resemble the

adult at all, but is more akin to that of *Corixa*, and the entire form of the insect in these stages is very different from that of the adult."

The above was written in 1897. Little more has been added since that time, due to the difficulty of keeping the nymphs alive under laboratory conditions. Bueno, 1905, reported his failure to get them beyond the second or third instar.

Hoppe, 1912, in his paper on "Die Atmung von *Notonecta glauca*," makes a few remarks on the life history, noting five nymphal instars.

The writer, 1917, published an account of the biology of *Notonecta undulata*, and during the year 1917 was able to study the biology of three other species, *N. variabilis*, *N. insulata*, and *N. irorata*, which are found in the waters about Ithaca, N. Y. The experience gained in studying the behavior of *N. undulata* was found useful in bringing these species through their transformations.

The behavior of the back-swimmers, especially with reference to respiration, has been quite fully treated, though even here there are problems as yet unsolved.

Brocher, 1909 and 1913, and Hoppe, 1912, have made extended studies on the respiration of *N. glauca* and Christine Essenberg, 1915, of Berkeley, Cal., has written upon the behavior of four California species.

ECOLOGY.

The members of this genus have been made the object of an ecological study by Bueno, who presented his notes in his "*Notonecta* of North America." He says in substance that *N. undulata* hangs from the surface almost constantly and its raptorial claws can be seen forming little elevations as it hangs head down. *N. insulata* seems to prefer to float in clear spaces in clear cold pools, about midway between the bottom and surface. "On the other hand, *N. irrorata* and *N. uhleri* appear to like to hide among the roots of plants growing at the water's edge, to which they cling. The former may at other times also be seen floating below the surface, in the shadow cast by bank or fallen tree or broken branch. The habits of *N. variabilis* differ somewhat from the others, since this bug prefers to lurk among the water weeds at the bottom."

Oviposition. Until recently there seemed to be a distinction between the manner of oviposition of the common European species and our American forms, the common *glauca* of Europe placing its eggs in the tisues of plants, as noted by Regembart in 1875, and our American species affixing them to the surface of plants, as noted by Bueno and Essenberg. The writer reviewed the question in the "Egg-laying habits of *Buenoa margaritacea*" at which time he supposed all American species placed their eggs upon the plants. In a footnote to his paper recording the "Life History of *Notonecta undulata*," he recorded the fact that *N. irrorata* places her eggs in plant tissues even better than *N. glauca*. In another paper appearing in the *Entomological News* "Concerning the oviposition of *Notonectæ*," the writer presented the evidence as to the manner of oviposition of the various members of the genus, basing this evidence upon the study of the female ovipositors. The plates submitted with this paper are here reproduced to indicate the interesting study

which they present concerning form and function. The following species were studied and figured: *N. lutea, N. raleighi, N. undulata, N. variabilis, N. insulata, N. glauca, N. mexicana, N. shooterii, N. irrorata, N. uhleri,* and *N. indica.* Sufficient material of *N. undulata, N. variabilis, N. insulata* and *N. irrorata* were examined to indicate that the ovipositors of these may possess specific differences. Kirkaldy long ago gave up the idea of distinguishing the males by their genetalia, but it would be worth while to look into this matter again.

N. glauca, N. lutea, N. irrorata have long ovipositors and place their eggs in plant tissues. The others merely affix them to the surface, attaching them there by means of a colorless, water-proof glue. See plates XIX, XXI and XXII with accompanying legends.

Migrations. These insects habitually fly from their winter quarters to their breeding grounds in spring, as has been noted long ago. There are some very interesting notes on the migration of back-swimmers, one so curious that it is reproduced in substance here:

"In evening twilight of a pleasant September day, 1846, Sir Geo. Simpson encamped for the night, on his route from Red river to the headwaters of the Mississippi, in the vicinity of latitude 48° north and longitude 95° or 96° west. While supper was preparing he perceived something falling on his hat like drops of rain; and as there were no clouds to be seen, presumed that it could not be rain. On looking on the ground near the fire he saw that the falling objects were winged insects, which, although unable to fly, had life and motion. The number rapidly increased so as to give great annoyance, and continued till the ground was covered by the shower. On the following morning Sir George found that this shower extended from 25 to 30 miles in the direction he was traveling. No information as to its extent other directions. It was observed that soon after the shower the weather changed from warm to cold. It is therefore probable that the whole of this immense swarm of insects encountered the cold current, and were paralyzed and precipitated thereby. They all died soon after falling. In no instance were they seen to revive after coming into a warmer atmosphere."—*Amer. Journal of Science and Arts for November, 1847.*

The above appeared in *American Journal of Science and Arts* for November, 1847, by Prof. Forrest Shephard. It relates to the same migration that was mentioned by the writer in his quotation from S. G. Simpson in a former paper.

Means of Defense. All collectors, from Frisch, 1728, to present day, testify to the stinging propensities of uncautiously handled back-swimmers. If handled carelessly, they pierce one with the stylets of their beak, the burning, painful sensation of which may last for some time. Doctors Riley and Johannsen considered it of sufficient importance to figure the salivary apparatus of *Notonecta* in their "Hand Book of Medical Entomology."

Some species, *N. variabilis,* for instance, secrete, when handled, a milky fluid which oozes from the sides of the thorax beneath the wings and at the base of the so-called coxal plates. This fluid reminds one of a similar secretion of Gyrinids.

Enemies. Predators as they are, their lives are in constant peril. The newly hatched are eaten by their older brothers. Woe betide the

helpless nymph caught by a hungry neighbor while disengaging himself from the integument of an abandoned instar. Other water bugs of his size and larger, with predatory tendencies, water beetles, etc., are his enemies. Needham figures a nymphal dragon fly in the process of devouring an unfortunate back-swimmer. In the matter of parasites, he is burdened with the usual Hydrachnid mites, and a tiny wasp parasitizes its eggs

From the larger forms of life the back-swimmers enjoy considerable measure of immunity. Seldom, indeed, have they been taken in the stomach contents of fishes and the like. Little wonder that they are a dominant form of pond life. The abundance of back-swimmers and boatmen in the same pool has been difficult to understand until recent investigations into the habits of these two types have cleared up the question.

Notonecta insulata.

This large back-swimmer compares favorably with *N. irrorata* in size, yet even its largest varieties could be distinguished readily from the latter by the marked differences that exist in the shape of their heads and bodies. This fellow was less common at Ithaca than *N. irrorata.* It remains much submerged and this may account for the infrequency with which it was captured. On April 29, two mating pairs were taken in the west pool of Ringwood Hollow. They were brought to the laboratory, and when placed in a battery jar, mated again. They remained in copula as long as the observation was continued—a half hour or more. Since Hagemann, according to Wefelsheild, reports *Corixa* remaining in copula 1 to 2 days, and from our experience with other water bugs, we would not be surprised at a long duration for the process in this bug.

During the day, April 30, 14 eggs were laid—large, white eggs, attached to the stems. These eggs are considerably larger than those of *N. irrorata.* Thirty eggs were present May 4. One of the males died May 6 and was pinned up. On May 10 there were 26 more eggs. Thus in the first twenty-four hours the two females averaged 7 eggs apiece, this average falling off somewhat later. On May 9 a few of the eggs were showing pink eye spots. Some of these were photographed and are shown on plate VIII. May 19 many of the eggs showed very dark red eye spots and gave evidences of hatching shortly. The first hatched on May 23. A careful study of these newly hatched was disappointing in a way. Instead of coming to surface, they remained submerged. The newly hatched are white with transparent abdomen and limbs. The guard hairs of the abdomen hang limp. Two little fellows hatched at 1:10 p. m. They were active ten minutes later, making series of backward somersaults, then resting as though exhausted. All efforts appear to be to attain the surface film, but at 2:20 they were still unsuccessful, and when resting on the bottom of the jar were indifferent as to which side was up, back or venter. Five o'clock came and still they were below, the guard hairs hanging limp upon the venter. Finally the next day some fresh water was added and some bubbles left upon the surface. Into these I coaxed one nymph, with the result that it filled its guard hairs instantly and darted below! This fellow was transformed of a sudden into a very ac-

tive creature. The other nymphs were still slow and inactive. On May 24, at five p. m., two were still alive, though their guard hairs were non-functional. This tardy coming to the surface seems to be a feature in the behavior of the newly hatched of this bug. The habits of the adult and the needs of the larvæ appear to be different from the others studied.

The last adult of the overwintering generation was taken early in July. The species was too rare to accord satisfactory study in nature. Here follows a description of the egg and young nymph:

The Egg.

Size. Length, 2.21 mm.; height, viewed laterally, .78 mm.; width viewed from above, .754 mm.

Color. White, with surface quite strongly reticulate so that surface is rough. The chorion is quite tough.

Shape. Elongate oval, micropylar end somewhat truncate; caudal end more pointed.

As with other Notonectid eggs the micropyle is a curved truncate cylindrical peg.

The egg is attached to the plant stem or other support by a transparent pad of mucilaginous material. This egg is proportionately quite large. See the drawings on plate XIX. They are drawn to the same scale and show how much larger this egg is than that of *Notonecta irrorata,* a bug of nearly the same size.

First Instar.

Size. Length, 2.73 mm.; width of both, 1.248 mm.; width of head, 1.092 mm.; width of front of head between the eyes, .546 mm.; distance between the eyes, .442 mm.

Color. Body white and abdomen and limbs of newly hatched transparent, the hairs smoky, eyes red and prominent, antennæ and beak dark. The limbs are also sometimes dark in the older nymphs.

Structural Characters. The antennæ are directed downward, 3-segmented, basal segment very short. The tarsi are 1-segmented and end in two claws each. The claws of the hind tarsi are not conspicuous. The middle femora have, on their posterior margin, at least 2 spine-bearing tubercles. The posterior femora have 10 or 11 stout spines (on posterior margin) plus 2 longer ones at distal end.

Notonecta irrorata.

Habitat. This is a handsome bug of velvety brick red and black, and one of the largest species of back-swimmers. Bueno tells us that it likes the shadows of the bank, of overhanging limb, or of aquatic vegetation. Surely its mottled pattern of dark colors would serve it well in such haunts. We have found it very abundant at the field station and in the Meadow pool at Ringwood Hollow, Ithaca, N. Y.

Hibernation. It spends the winter months in the deeper ponds and spring-fed open pools, flying from these quarters to shallower waters for breeding. At Ringwood Hollow this bug was present in considerable numbers in the rather deep leaf-strewn pool just west of Winterberry

pond in late autumn and early spring. The migration from this pool occurred in a very few days of warm spring weather. A few days after taking mating pairs in numbers on April 29, the pool was almost deserted, scarcely one was to be found. An examination of the Meadow pool, a quarter of a mile away, found them very abundant. Subsequent surveys indicated that the latter pool was the breeding place of this bug, for nymphs of this species swarmed the pool, forming, in fact, the dominant type of insect life. Very few nymphs were ever taken in the winter-quarters pool. The migration to deeper ponds and pools is doubtless due to a desire to secure unfrozen waters. They have been observed swimming slowly beneath the ice at the Field Station, Ithaca, N. Y., in early February.

Mating. The mating begins in early spring, and occurs in the water, the male usually occupying a position to the left side of the female. The pairs have been observed to remain in copula for two and three hours, swimming about in the water, and the female even catching prey. Mating pairs may be taken over a considerable time, but about the last of April they appear to be most active.

Oviposition. In the matter of oviposition this species is the most interesting of all the members of the genus in this country, for, as elsewhere stated, it inserts its eggs in the tissues of plants. On plates VIII and XXII are shown the photographs and the figures of the eggs inserted in moneywort and in water-soaked typha blades. One figure shows two eggs inserted in a bit of water-soaked leaf of typha through one aperture. As a rule, however, they are imbedded singly, wholly or in part, depending upon the nature of the material serving for support. The cephalic end of the egg is directed toward the opening. Females deprived of vegetation of sufficient diameter to permit the insertion of eggs (such as Chara) will hide them in mud and debris lodged in the axils of the plant. In only two cases were they loosely affixed to the chara.

Incubation. The first eggs discovered were on May 12. They may have been laid before this date, for they began hatching May 18. In another aquarium some eggs were laid May 12, red eye spots were showing June 2, and hatched by June 8. Another lot, laid between May 25 and May 27, showed red eye spots June 11, and began hatching a few days thereafter. Thus the egg stage of this species is comparatively long—some two or three weeks, or even longer.

Hatching. The time of hatching in the laboratory began May 18. The first nymphs were taken in nature during the first week in June.

The hatching process has been outlined in connection with *N. undulata*, but some special features that were observed in connection with this species are worth noting.

In attempting to study the behavior of newly hatched nymphs, the eggs were kept under constant observation for many hours. One of the striking facts of interest is the activity of the nymph within the egg some hours before hatching.

One evening when a number of eggs were expected to hatch they were

watched closely for hours. One attracted attention especially because the embryo was seen to be moving within its shell. One observation found it in the position shown in the drawing on plate XXII, fig. 3. A little later the embryo had rotated upon its longitudinal axis so that the eye spot on the right side in the drawing was on top. Fifteen minutes later the right eye had continued its rotation until it held the position on the left side. In ten minutes more it was in its original position again. This movement of the embryo, as followed by the pink eye spots, continued at intervals for several hours. Emergence was expected at any moment, but did not take place for many hours after the writer had despaired of seeing the event take place.

Number of Instars. There are five instars, which after the first are much alike, and to be distinguished by the dark markings on the sides of the abdomen.

Maturity. The overwintering adults mate and begin egg laying in May. The first nymphs in nature were noted in the first week in June. By the last of June they were in all stages up to the fourth. On July 1, they were coming into the fifth instar at the Meadow pool, where the nymphs were most abundant. Frequent visits were made to this pool at Ringwood to observe the first adults of the new generation. While there were overwintering adults alive in the laboratory, careful collecting showed they had disappeared from this pool, so great interest was aroused in the behavior of this species in this Meadow pool. On July 7 there were many fifth instar forms, but no adults. I brought some of these to the laboratory and placed them in an aquarium, where the first adult came forth July 18. The next day a trip was made to Ringwood, and the Meadow pool contained many newly emerged *N. irrorata* adults! Beautiful fellows they were, too, with their velvety, richly-colored backs! There is no mistaking these fellows for the older generation. Now, the next step was to determine if these fellows would bring forth another generation. Adults were brought to the laboratory and confined in an aquarium. The writer left them in the care of a friend, who reported that no eggs were deposited, and some were alive on October 22, when the experiment was abandoned. Only three or four individuals were followed, and the sex of these not fully established, so little data can be given concerning any evidence of a second generation of this species in New York state.

LABORATORY REARING.

One series will indicate the various stages and the duration of time required for each. On April 20, three *N. irrorata* taken at Six Mile pool were placed in a glass battery jar with some fresh sprigs of Moneywort taken from above the water line. On May 12 eggs were discovered imbedded in the stems of the plant. These began to hatch on May 18. Some of these changed to second instar June 1, to the third June 9, and to the fourth June 20, to the fifth July 1, and to the adult the middle of July. These nymphs had been isolated in small stenders and jelly glasses and fed Cyclops and Ostracods. The first-instar fellows were seen to eat Ostracods nearly as large as themselves. When first hatched the

nymphs are clear white, with red eyes as seen from above. The limbs are transparent as is the abdomen also. The antennæ, claws and hairs are dark. In ten minutes the limbs begin to get smoky. When they have hatched within the water the guard hairs of the abdomen hang limp. The insect seems water-logged. It comes up to the surface head up, and repeatedly sinks back to the bottom exhausted. Finally a stronger effort than before enables it to hook the front claws into the film, then after a sudden turn it goes down with an air bubble imprisoned beneath the abdominal guard hairs.

In a battery jar the adults were active for a long time. The adults liked to cling beneath the rubbish and Moneywort tangle. They were fed the nymphs of damsel flies and Corixids. On June 25 the eggs were present in all stages from those showing red eye spots to those newly laid. The last of the three backswimmers was alive and active July 9 and the notes fail to show her fate.

This account shows that the egg laying can be carried out under laboratory conditions and that it lasts from early May to the end of June at least.

Fecundity. On March 26 a female was dissected and found to contain 252 ova, several of which were nearly ready for laying. The period of oviposition lasts from early spring until into June, in the laboratory not more than a half-dozen eggs being laid on any one date.

Longevity. Adults certainly are capable of living at least a year. There is evidence to indicate that adults of the previous year may occasionally live over until the new generation comes on in July. They are few, however. If cared for in the laboratory they might exist well through the second season.

Food Habits. Like others of their kind, they are predators. In their first stages in the laboratory they were given Ostracods and other small Entomostraca, also Corixid nymphs. By the time they reach the third instar they can master adult corixids of *Palmocorixa* genus (when they can catch them.) As elsewhere noted, the adults show discrimination. They caught but immediately liberated some pink Phyllopods offered them.

Behavior. The late instars are given to spending considerable time at the surface, like the *N. undulata.* The adults, however, are not so in evidence and come out in the sweepings of the net as pleasant surprises to add zest to the activity of the amateur collector.

Description of Stages.

Egg.

Size. Newly-laid egg, length, 1.51 mm.; diameter, .572 mm.

Shape. Elongate oval, but shorter in proportion to its length than *N. variabilis*, *N. undulata* or *N. insulata.* In lateral view the anterior end of the egg is seen to slope back from the base of the micropyle more than the others. (See pl. XIX, fig. 6.) It is this portion of the egg that is exposed as it lies in the plant stem.

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* Frisch, 1728, said that the young stages of *N. glauca* were more often seen than the adults.

Color. White when first deposited, then amber as the red eye spots begin to develop. The ventral surface of the embryo (upper surface of egg) begins to show sooty black. The micropylar plate darkens. The micropylar tube remains white. Later the darkening embryo within lends a color pattern to the outside.

Structural peculiarities. Shell rough, tough, irregularly, hexagonally reticulate. The egg increases in size as embryo develops within.

First Instar.

Size. Length, 2 to 2.6 mm.; width of body, .99 mm.; width of head, .91 mm.; width between the eyes at front of head, .494 mm.; distance between the eyes, .364 mm.

Color. Much darker than any other backswimmer nymphs examined. In ventral view, the legs, beak, hairs and venter, sooty black. Eyes dark red. Hind tarsi marked transversely by a broad band of lighter color and the margins of first three or four abdominal segments lighter also. Frons lighter than beak. In dorsal view, the head is light between the eyes. Thorax and abdomen dark save where the light band of the head extends backward on the thorax to the abdomen. Margin of basal segments of abdomen somewhat lighter. (See drawing, pl. XIX, fig. 2.)

Structural peculiarities. Besides its much darker color, which readily separates it from the other nymphs, the posterior margin of the middle femur is equipped with only one well-defined, spiniferous tubercle.

The first instar nymphs of the four species reared may be distinguished as follows:*

A. Color dark, smoky testaceous. Posterior margin of middle femur with one long spine on a tubercle. *N. irrorata.*

AA. Color light. Posterior margin of middle femur with 2 spines on tubercles.

- B. Length, 2.6 mm. or more. Posterior margin of hind femur with 10 to 11 stout spines, plus 2 longer ones at distal end. *N. insulata.*
- BB. Length, less than 2.6 mm. Posterior margin of hind femur with 7 or 8 short spines, plus 2 longer ones at distal end.
  - C. Legs conspicuously banded. Spines on posterior margin of hind femur not conspicuous. Margin of abdomen narrow, rather slender body. *N. variabilis.*
  - CC. Legs not conspicuously banded. Spines on posterior margin of hind femur conspicuous. Margin of abdomen wide, robust nymphs. *N. undulata.*

Second Instar.

Size. Length, 3.27 mm.; width of body, 1.5 mm.; width of head, 1.2 mm.

Color. For color pattern see later instars.

Structural peculiarities The median abdominal carina is now present on the venter and margined with hairs. Posterior margin of mesothorax more arcuate than in first instar. The distance between the eyes at ver-

* First instar Notonecta nymphs have no ventral abdominal median carina.

tex plainly less than the width of one of the eyes. The femora of the middle legs now have two strong spines on the posterior margin. The basal one is borne upon a strong tubercle.

Third Instar.

Size. Length, 3.51 mm.; width of body, 2.21 mm.; width of head, 1.56 mm.

Color. For color pattern see later instars.

Structural peculiarities. Ventral view: The limbs are all equipped with spines. Some of these on the front and middle legs are arranged to effect a loose guard of hairs when the limbs are flexed. The front and middle limbs are also flat or concave on their posterior side and guarded on either margin by several spines. The front tibia has an irregular row of about six in the ventral edge of its posterior margin, and a definite row of the same number on the dorsal edge of this posterior margin. The tarsus is shorter than the tibia and has two spines on either margin and ends in two well-developed, subequal claws. The middle femur is thickened and on its posterior border are three long spines, the basal one on a strong tubercle and a short peg-like one. The middle tibia has 3 spines on its anterior margin, six short ones on the ventral margin of the posterior side, and three long ones on dorsal margin of this same side. The dorsal caudal margin of tarsus is provided with four spines and the tarsus is terminated by two unequal claws, the upper one of which is nearly a half larger than the lower. The hind limbs are strong and furnished with many short spines. The posterior margin of hind femur has a row of these short spines, eight or nine large ones quite evenly distanced one from another, and three spines are present at distal end of the ventral side of femur. Several rows of short spines on tibia and tarsus and swimming fringe on both of these segments.

Dorsal View. Posterior margin of mesothorax more deeply arcuate, the wing-pads extending back more than one-third of the length of the margin of the mesothorax and metathorax together. Margins of abdomen barred with dark markings, base of second abdominal segment very dark also.

Fourth Instar.

Size. Length, 7 mm.; width of body, 3.12 mm.; width of head, 2.08 mm.; distance between eyes at vertex, .91 mm.; distance between eyes at closest point, .52 mm.

Color. As in fifth instar, save the dark band on mesothorax. Wing-pad is single and broad.

Structural Peculiarities. Ventral view: General arrangement of spines on the legs about as in third instar; front tibia as in third instar; front tarsus shows the two spines on the dorsal edge of the posterior margin, the other spines obscure. Middle femur now shows a definite tuft of about four strong spines arising from the tubercle, two other strong spines (sometimes a weaker one also) and a black-tipped spur or tooth not far from distal end of femur. The middle tibia has six spines either side of the posterior surface and three or four on the rounded

anterior surface. The middle tarsus has an irregular row on lower posterior margin and a definite row of four spines on the upper. Tarsal claws unequal as before. Hind legs as in the other instar in general equipment, posterior margin of hind femur with a row of about 30 short spines of nearly equal length, the distal pair being a little stronger than the others, and close together. Three spines mark the distal ventral margin of the femur. The hind tibia possess tibial combs each in two groups, one consisting of four stout spines, and the other of three.

Dorsal View. The wing-pads of mesothorax extend back more than one-half the length of the margin of mesothorax and metathorax taken together.

Fifth Instar.

Size. Length, 10.6 mm.; width of body, 5.1 mm.; width of head, 2.86 mm.; distance between eyes at vertex, .936 mm.; distance between eyes at narrowest point, .52 mm.

Color. In dorsal view, eyes dark red, thorax white with greenish tinge; prothorax with a smoky band near each lateral margin and parallel with it. Postero-lateral angle smoky. Mesothoracic wing-pad with two longitudinal smoky bands joined posteriorly by the dark band of the apical margin. Posterior margin of metathorax marked by a smoky line that diffuses into a band at lateral margins. The abdomen is chalky white, strongly marked by transverse bands and spots of smoky black. Basal portion of abdomen is crossed by three rather wide bands. The following two bands are broken on the dorsum, but the two caudal transverse bands are broad and heavy.

In ventral view, a median dark band divides the head longitudinally. The base of the beak and beak dark; limbs testaceous, equipped with black hairs, and femora with longitudinal stripes of darker color; connexivum with six pairs of dark rectangular spots; guard hairs dark.

Structural Peculiarities. Ventral view, median abdominal carina long, in three sections and extending nearly the length of abdomen; front femur with 4 strong spines on upper margin of posterior side; tibia, 6 spines on either edge; tarsus as in 4th instar. Middle femur now has, besides this clump of spines on the tubercle, four other spines and the spur, which is now longer than in previous instar. Posterior margin of hind femur with about 44 short spines plus three longer ones at distal end. Distal ventral margin of femur with five strong spines. Tibia with distal ventral margin equipped with two sets of four or five strong spines.

Dorsal view: Wing-pads extend back to abdomen in this instar.

Summary. This bug has been reported from New York. It prefers clear waters where it frequents the shelter of shaded places. The eggs are placed in the tissues of aquatic plants instead of upon the plant as is the case with the other members of the genus. Egg laying begins in May and the adults of the first generation come to the adult stage in mid July in New York. There is insufficient evidence to state whether a second generation appears.

Biology of *Notonecta undulata* Say.

Habitat. *Notonecta undulata,* besides being the most widely-distributed form, seems to be able to adapt itself to a wider range of circumstances than most of the others. The writer has taken it in clear spring-fed pools in New York and in the stagnant scum-covered waters of muddy ponds in Kansas. Uhler, 1876, says "it inhabits the foulest pools, in dirty slush and slimy ponds it revels in full enjoyment of the filth."

Barber, 1913, in a popular paper on aquatic Hemiptera, makes a similar reference to its habitat. Thus it may be noted to be less sensitive than many others of its genus to its environment. When the small bodies of water recede during the prolonged period of dry weather, which we sometimes have in late summer in Kansas, it is among the last to take wing to more favorable situations, a fact which is not to be accounted for on the basis of weak powers of flight, for it does on occasion fly very well, as appears to have been noted for the European forms at an early date. Aldrovandus spoke of them as amphibious bees and Swammerdam, at the close of his discussion of the *Notonectæ,* a name applied to them by Mouffet, 1634, makes the following interesting remark in regard to the migration of water bugs: "As all the insects hitherto enumerated have wings, some of them flying in the daytime and others at night, it is easy to conceive that they may be very speedily generated in all standing waters."

In the first warm days of spring, the writer has observed them coming by the dozens and alighting in a small road-side pool. Thus their range, which was restricted by the drouth of the previous fall, was again extended to the many favorable pools of spring and early summer. There are several records of Corixid migrations in this country but only one, so far as the writer knows, for *Notonecta.* In September, 1846, near the head waters of the Mississippi, S. G. Simpson reported a swarm of "*N. glauca,*" which extended over 25 or 35 miles. This species, if a Notonectid at all, was doubtless the common *N. undulata.*

Hibernation. The adults may be taken any time during the winter when the waters are open enough to permit collecting. They pass the coldest portion of the year in the mud or among the rubbish and dead leaves in the pool. They can even spend as long as six weeks in damp piles of dead sticks, so it does not necessarily follow that they perish because pools diminish during weather when they are but sluggishly active.

Mating. Mating takes place with the first warm days of spring, and as with other water insects takes place beneath the surface and lasts for some time.

Oviposition. The eggs are glued to supporting vegetation, sticks, posts, rocks, tin cans, or even to snail shells that lie submerged. A very satisfactory idea of the eggs may be obtained by viewing the photograph on plate XXI.

Incubation. The egg stage varies from five days to two weeks, depending upon the temperature.

Hatching and Behavior of Newly Hatched. Hatching takes place upon bursting the cephalic end of the egg as shown in the photograph. The nymph comes forth swathed in a clear membrane, gradually working its way, by backward and forward movements, till it is nearly clear of the egg shell, whereupon the embryonic sheath splits and slowly the new bug frees itself, the swimming legs being the last to leave the shell. As the legs are freed they spring out into position. When at last the little bug is clear, it rests as though exhausted, then it makes, during the next fifteen or twenty minutes, intermittent endeavors to attain the surface. In these efforts it approaches the surface head uppermost and is heavier than the water—dropping to the bottom as soon as its struggles cease. Finally it may succeed in hooking a front claw into the surface film where it will hang suspended for some minutes. Finally it turns on its side, pierces the surface film, then darts below, the guard hairs closed over a bubble of air. Up to this time the guard hairs of the abdomen have rested limp against the body.

Number of Instars. There are five nymphal instars.

Food Habits. The food habits of the first three instars are very interesting to watch. The little nymphs make a specialty of Ostracods and other little Entomostracans. They will devour each other and thus each little nymph must be isolated if he is to grow up.

Behavior. This species, more than any other, rests at the surface film. Christine Essenberg has written much concerning four species of Backswimmers.

DESCRIPTION OF STAGES.

The Egg.

Size. Length, 1.625 mm. to 1.813 mm.; diameter, .5 mm. to .6 mm.

Shape. Elongate oval; becomes plumper as embryo develops within.

Color. White when first deposited. The embryo lies with its back to the attached side of the egg as a rule. After a few days incubation the eye spots begin to appear as faint pink blotches, darkening as development takes place, till shortly before hatching the black hairs bordering the various portions of the body of the nymph are visible through the chorion. The surface of the egg is tough and rough, due to the fact that it is sculptured in irregular hexagons. The micropyle is a curved tube arising from a circular differentiated area as shown in the drawings on plate XX.

First Instar.

Size. See table below.

Color. General body white, eyes red, hairs and spines black, antennæ smoky black. When first hatched the abdomen especially transparent and the movements of the organs plainly visible within. Tarsal claws all conspicuously black.

Structural Peculiarities. The most characteristic feature of the first instar is the absence of the tuft of hairs which in all succeeding instars is found on a median ventral carina of the abdomen. The eyes are relatively far apart. The antennæ are apparently 2-segmented and di-

rected downward (really three segments). The tarsi are all 1-segmented and end in two claws. The tarsi of the hind legs are fringed with hairs. The middle femora are furnished on their caudo-ventral margins with two strong bristles set upon elevations.

Second Instar.

The presence of the tuft and fringe of hairs on the ventral abdominal carina is the chief addition over that of the previous stage. The rear margins of the middle femora are now equipped with three strong bristles and there is a suggestion of the tooth or spine that becomes prominent in the succeeding instar. Antennæ 3-segmented. First segment short, disc-like, second somewhat globose and third elongate.

Third Instar.

The caudal margin of the mesothoracic femur now carries a well-developed tooth as well as the three stout spines noted in the second instar. Tibia and tarsus of hind leg now fringed with hairs—wing-pads as in figure 4, plate XX.

Fourth Instar.

The middle femora now bear very stout processes in the line of the caudal row of spines. A series of short processes on the ventral side of this segment take the place of minute rugosities of the previous instar.

Fifth Instar.

The tooth or strong spine on the mesothoracic tibia is now extremely wide at its base. The limbs are stouter than previously and the wing-pads now have the position shown in figure 4 of plate XX.

In the table below the measurements are in millimeters and based on reared material. The adults are certainly smaller than those taken in Ithaca, N. Y., though practically the same as specimens from nature in Kansas. These figures are intended to help in determining an instar. The series measured is not large enough for purposes of generalization.

TABLE OF MEASUREMENTS.

Stage.	General Measurements.					Hind Leg.			Middle Leg.			Fore Leg.		
	Length.....	Width.....	Width Head.....	Between Eyes.....	Synthl. to Vertex.....	Femur.....	Tibia.....	Tarsus.....	Femur.....	Tibia.....	Tarsus.....	Femur.....	Tibia.....	Tarsus.....
1st instar....	2.125	1.062	.833	.43	.818	.687	.707	.875	.437	.437	.313	.37	.375	.275
2d instar.....	3.1	1.41	1.06	.395	.73	.975	.975	1.12	.63	.625	.437	.5	.53	.37
3d instar.....	4.66	2.	1.4	.4	.66	1.47	1.47	1.53	1.	1.	.65	.75	.762	.57
4th instar....	6.125	2.75	1.87	.53	.66	2.125	2.	2.	1.38	1.37	.93	1.	1.12	.75
5th instar....	8.5	3.5	2.5	.66	.582	3.1	2.89	2.75	2 1	2.	1.16	1.5	1.58	1.12
6th (male)....	11.4	4.	2.86	.4	.4	4.1	3.48	2.86	2.68	2.57	1.43	1.94	2.28	1.26
6th (female)..	11.4	4.28	2.97	.42	.41	4.28	3.54	2.97	2.85	2.68	1.66	2.	2.28	1.43

General Notes on Development. There are certain constants of structure that are carried through all the nymphal instars. The mesothoracic

legs may serve as an illustration of this point. In all the instars the tarsi end in unequal claws as in the adult, and the tibiæ possess a row of five bristles on their caudo-ventral margin and the tarsi three such bristles.

The metathoracic tarsi end in an unequal pair of claws which are prominent in the first instar (plate XX, figure 10), and which become less and less conspicuous as development proceeds till in the adult stage their similarity to the other structures of the swimming leg has led to the common statement that the tarsal claws of hind legs are absent in the adult. Upon transforming to the adult stage the 1-segmented condition of the tarsi is replaced by a 2-segmented tarsus and the 3-segmented antennæ become 4-segmented. (See plate XX, figures 6 and 7.)

The eyes occupy an increasingly large proportion of the head in successive instars, a point not properly indicated in the drawings which were made from living bugs in the water.

Summary. Notonecta undulata is the most widely distributed of all our backswimmers. It lives well in the aquarium and may be reared from deposition of the egg to the adult stage in some forty days if placed in isolated jars and given proper attention. The young stages thrive on a diet of Ostracods and the advanced nymphs do very well on immature and small Corixids for a food supply. In Kansas there are two main broods in a season, one reaching the adult stage in June, the other in August. Since these insects draw quite largely in their young stages upon the Ostracods and similar organisms, which represent a chief food supply for young fish, as well as preying upon a small fish directly, as has been noted several times, they deserve more careful study. This task is greatly facilitated by a workable key to the species and by some knowledge of their feeding habits.

Biology of *Notonecta Variabilis.*

This species was very abundant in the pools about the Field Station, Ithaca, N. Y. The writer has never taken it in Kansas, although it should occur there. It likes fresh water, and clings to submerged tangles of water plants.

The Egg.

The egg is deposited upon a pad of gelatinous material. This egg appears to be more truncate at anterior end than the other eggs.

Size. Length, 1.69 mm.; width, top view, .65 mm.; width, side view (heighth), .78 mm.

Color. Surface is hexagonally reticulate; pearly white when first deposited, then turns first amber and then smoky as embryo develops, especially at anterior end. Micropyle tube is long and directed toward attached side of egg.

Shape. As in other species.

First Instar.

Size. Length, 2.08 mm.; width of body, .936 mm.; width of head, .78 mm.

Color. Dorsal color greyish white, eyes red, margin of abdomen and limbs pale testaceous banded with dull smoky brown or black.

Venter. Hairs dull black, beak and part of frons very dark smoky, as are the antennæ, which are directed downward. Coxæ, trochanters and femora dark, fore and middle tibiæ dusky, hind tibia darkest in middle, distal end light. Tarsi all dusky, with broad transverse median band of testaceous. The color marking of hind leg is distinct. The outer one-third of tibia pale, rest of segment smoky testaceous. Tarsus very dark smoky, almost black, with a wide transverse pale band occupying more than one-third of the segment. This leaves both ends of segment dark.

Structural Peculiarities. No ventral abdominal median carina present. Distinguished from other first instar nymphs by table given under *N. irrorata.*

Biology of *Buenoa margaritacea* Bueno.

So far as the writer knows, there has not been an account of the biology of any species of either this genus or *Anisops,* its near relative, aside from his own notes published in the *Entomological News* in 1917. In this paper he presented some observations on *Buenoa margaritacea* Bueno. This is a slender silvery backswimmer, more or less of pink showing upon the dorsum of the thorax. The venter of the abdomen is a deep red in living specimens. This darkens in museum material, and has led to the error of the description in calling it black. Uhler said that *Anisops platycnemis* preferred the cold spring water in Maryland where he had taken it late in October after the frosts had set in. Bueno notes that it prefers the more open waters, and the writer has found it in muddy ponds in Kansas where it floats submerged in open water.

Oviposition. Attempts to secure eggs of this bug failed until examination of the ovipositor made it apparent that the eggs were hidden in plant tissues. They were then found in floating plants in the pond, and secured in the aquarium by providing cattail leaves and smartweed stems. One uprooted smartweed plant, floating in the Smith pond, was almost riddled with oviposition incisions. Not only were the stems swollen and distorted by the many eggs they contained, but the leaves were employed as nidi with varying degrees of success. The leaves were punctured, and the egg, when present, rested suspended beneath, attached by the collar shown in the drawing on plate XXIV, to the upper surface margins of the incision. The many perforations or slits through the leaves gave their testimony to the many failures in attempting to employ so thin a structure for nidification. The eggs are placed in the plant tissue with one bit of surface exposed.

Number of Instars. There are five nymphal instars, and the duration of the various stages is much the same as in other back-swimmers. Adults are to be taken from early spring to late fall. About the middle of June they are most abundant in all stages of development.

Food Habits. One striking point in their biology is the adaptation of their two slender anterior pairs of limbs to food getting. The food of these insects consists of the small entomostracan Crustacea, and the four anterior limbs are margined with rather long spines which form when

flexed a splendid crib for the retention of these little animals. Sometimes a half dozen or more are detained thus at one time. We have attempted to illustrate this device on plate XXIV, showing the limbs open in one drawing and flexed in another. They sometimes attack other insects, such as Corixids, but rely almost exclusively upon the little organisms named.

Behavior. These insects do not rest at the top as does *Notonecta undulata,* but may be seen swimming slowly, or even poising in midwater some distance beneath the surface. They do in fact seem in better equilibrium in the water than the *Notonectæ.* They come to the surface and expose the venter of the abdomen by the spreading of the guard hairs, as do the other back-swimmers when in poorly aërated waters.

The males possess stridular areas upon the inner faces of the femora and tibiæ, and also on the sides of the face at the base of the beak. These are shown in the drawings on plate XXIV. The tibial structure is borne on the inner face of a spur near the base of the anterior tibia. When the fore limbs are brought up to the head, it will be seen that the stridular areas of the limbs meet those on the base of the beak. See the figure on plate XXIV. The production of sound is doubtless the purpose of these structures. European workers have recorded Notonectids as capable of producing chirping sounds. Miall quotes Redfern to the effect that Notonecta makes a noise like the word "chew" repeated three times.

The Egg.

Size 1.125 mm. long by .406 mm. in its widest diameter. The size increases somewhat with the development of the embryo within, which causes a bulging of the stem in which the egg is inserted.

Shape. The egg is elongate oval when seen in surface view with the cephalic end the more pointed. (Surface view—the side, a portion of which is exposed to view as the egg lies embedded in the stem.) In lateral view it appears nearly straight in the outline of its upper surface, while the lower is quite strongly curved.

Color. Pearly white when first laid—the surface hexagonally reticulate as in the eggs of *Notonecta.* A smooth and shiny elongate oval area occupies the anterior half of the upper surface. This is the portion exposed and is margined by a whitish band which marks the union of the egg with the surface of the stem when "in situ." As the embryo develops, the entire egg becomes deep greyish yellow and the red eye spots and other red markings show through the chorion. The part exposed becomes dark amber in color and very shiny in appearance. The surface appears reticulate under magnification.

First Instar Nymph

Size. Body length, 1.85 mm.; body width, .625 mm.; head width, .5 mm.; distance between eyes, .156 mm. Fore limb: femur, .25 mm.; tibia, .35 mm.; tarsus, .25 mm. Middle limb: .387 mm., .333 mm., and .275 mm., and hind limb, .625 mm., .630 mm., and .625 mm. for femur, tibia and tarsus respectively.

Color. Ventral aspect: White—the abdominal fringe of hairs, the ventral abdominal tuft, the hair tufts before the hind coxæ and those of middle coxæ—black. The hairs fringing the hind tarsi are smoky black as are the middle and fore tibia. Eyes dark red. No indication of the red pigment in the abdomen so conspicuous in older nymphs and adults. White with the red eyes—the only conspicuous marking.

Structural Details. The absence of the median abdominal carina from the venter, as is the case also with *N. undulata* nymphs, is the first and most striking peculiarity. The interspace between the eyes is large. Beak four-jointed as in adult. Tarsi all one-jointed, terminating in two claws. The spiny armature of fore legs is more generalized than in later forms. The fringe of the hind legs confined to the margins of the tarsi.

The Older Nymphs.

In order that space may be conserved, a table of measurements for the various instars is presented below and a discussion of the changes in structure as development proceeds appended.

MEASUREMENTS IN MILLIMETERS OF NYMPHS OF *B. MARGARITACEA.*

Instar.	Body Measurements.			Leg Measurements.								
				Fore Leg.			Middle Leg.			Hind Leg.		
	Length.	Width.	Width head.	Femur.	Tibia.	Tarsi.	Femur.	Tibia.	Tarsi.	Femur.	Tibia.	Tarsi.
1st......	1.85	.625	.5	.25	.35	.25	.387	.333	.275	.625	.63	.625
2nd......	2.25	.702	.625	3.75	.438	.313	.5	.438	3.75	.75	.76	.81
3rd......	3.225	.938	.832	.5	.62	.487	.75	.625	.6	1.1	1.1	.975
4th......	4.5	1.625	1.063	.625	.75	.563	1.063	.875	.725	1.625	1.375	1.28
5th......	5.75	2.3	1.365	.8	1.2	.81	1.5	.625	1.125	2.25	1.85	1.6
6♂....	7.*	2.2	1.62	1.	1.35	1.	1.75	1.37	1.25	2.5	2.25	1.95
6♀....	7.5	2.2	1.75	1.	1.5	1.	2.	1.5	1.3	3.	2.62	2.3

* Bueno gives length of species 6.7 to 8.1 mm.; lat., 2.23 mm.

The adults of this species are separated in the synoptic table from the other two species on the basis of the body length, which is greater than 6 mm. This, with a diagnosis of the instars from structural characters, may serve to separate the nymphs of this species from those of the others. The table of measurements above is based on an average of ten specimens of each instar. A larger number would be desirable to obtain figures dealing with ratio of growth. The writer believes that an examination of a sufficiently large amount of material would show for head-widths and limb measurements a ratio of 1 : 1.25. That is to say, the width of the head of the second instar nymph would be approximately 1.25 times that of the first instar nymph.

Upon attaining the adult stage a sexual dimorphism becomes apparent. Besides the structural differences of the genitalia, the anterior legs

of the male possess on the inner faces of the femora and tibiæ peculiar stridular areas.

The tibial structure is borne on the inner face of a prominence, which is formed by the elevation of the inner angle or margin of the tibia near its base into a thin but elongate spur. This spur is lacking in the female, and not discovered in the nymphs. (See pl. XXIV, figs. 5 and 6.)

The Development Changes.

Head. The notocephalic margins of the eyes, which are near together and nearly parallel in the adult, are relatively much farther apart in the first instar nymph. In the newly hatched bug, the distance at synthlipsis is nearly 1/3 width of the head, with the margins of the eyes diverging broadly to the vertex. As the development proceeds from instar to instar the eyes are brought nearer and nearer to their relations in the adult where the synthlipsis is reduced to about 7.14 per cent of the width of the head.

The beak is 4-segmented and the antennæ of the nymphs have much the form of those in the adults.

Legs. The general form as in the adult. The tarsi of all legs 1-segmented and terminated by two claws. (The tarsi of the adults are 2-segmented and end in two claws.)

Wings. The wing-pads are very conspicuous even in the later nymphal instars. By the third instar the pads appear on the antero-ventral margins of the mesothorax as little flaps, the distal ends of which reach a position on a line with the trochanter of the fore leg when flexed. In the fourth instar they are much larger, the apices attaining to a position on a line with the distal end of the mesothoracic tibiæ when the limb is flexed. In the fifth instar they are still closely applied to the side of the thorax, but the tips of the more opaque pads reach a point on a line with the distal ends of the hind coxæ.

Habits of the Species. Buenoa margaritacea is the common representative of its genus in the ponds and pools of eastern Kansas. It appears to prefer the open water and is in much better equilibrium in its watery world than the *Notonectæ.*

Individuals of this species may be seen in large numbers swimming slowly or even poising in mid-water some distance beneath the surface. They abound in waters teeming with *Entomostraca,* upon which they largely feed, the crib formed by the closure of the anterior two spiny pairs of legs being nicely adapted to the retention of such prey. Their dexterity in the manipulation of this device and its efficiency in retaining small beings may be demonstrated quite readily under the binocular, and affords another of nature's illustrations of the fitness of form to function.

Like others of the predatory class of water bugs, they do, on occasion, fall upon Corixids and other forms than the Entomostraca, but not with the regularity of many of the others.

Adults appear from early spring to late fall. The eggs may be found in May, the nymphs begin to emerge by the middle of the month, and

by the 15th of June form a dominant species to be noted in all stages of development, from egg to adult, in waters suitable to their needs.

They are wilder and more difficult creatures to rear than the *Notonectæ,* but no less interesting objects of study. So far as the writer is aware, there has been nothing noted hitherto concerning their biology, and he is glad to record for them something of the economy of their lives.

Summary. This species is the common representative of its genus in Kansas ponds, where it swims well out from the shore and some distance beneath the surface. It feeds on the small crustacean life of the pool which it gathers in a spiny crib formed by the closing of the four anterior limbs. Its eggs are placed in the tissues of submerged plants fixed or floating in open water.

Family NAUCORIDÆ Fall 1814.

Fallen, Spec. Nov. Disp. Meth., pp. 3, 15.

A. Taxonomy of Naucoridæ.

Family characteristics. Broad, smooth bugs of moderate size, and greatly enlarged fore femora. The outer margin of the eye is continuous with the margin of the head, not protuberant, and caudal appendages are lacking. The antennæ are shorter than the head and lie concealed. Ocelli are absent. The beak is 3-segmented. Membrane of the hemelytra is without veins. The fore tarsi are 1-segmented; the middle and hind tarsi 2-segmented. The hind legs are not flattened for swimming. Aquatic, but little modified for such a life.

KEY TO GENERA.

A. Front margin of prothorax deeply excavated for the reception of the head. *Ambrysus.*

AA. Front margin of prothorax not deeply excavated for the reception of the head. *Pelocoris.*

Genus AMBRYSUS Stal. 1862.

These Naucorids have the head set deeply into the prothorax. The body is oval or sub-oval, and the head transverse, and truncate behind the eyes. Beak very short, lateral margins of pronotum entire, posterior angles, slightly retrorsely produced; gular and prosternal carinæ of equal height, continuous, middle of mesosternum longitudinally very obtusely elevated and subsulcate. Anterior femora very broad. Anterior tarsi single segmented. Claws lacking, tibiæ closely oppressed.

The following adapted from Montandon:

KEY TO AMBRYSUS.

A. Pronotum smooth, shining, without punctation on the disc, sometimes some rare indentations, set at regular intervals on the side.
  - B. Head very wide—as wide, including the eyes, as half the width of the rear of the pronotum.
    - C. With blackish spots or clouds. *A. pulchellus.*
    - CC. Without blackish spots or clouds. Head and pronotum entirely yellow, immaculate. *A. pulchellus var. pallidulus.*

KEY TO AMBRYSUS—*continued.*

BB. Head very sensibly narrower, including the eyes, less than half the width of the pronotum behind. Pronotum with a slight depression, sometimes very superficial, wrinkled transversely on the middle of the anterior border.

C. Coloration darker, segments of connexivum darkened with posterior angle a little prominent. *A. pudicus.*

CC. Coloration lighter, segments of connexivum not as above. *A. circumcinctus.*

AA. Pronotum densely punctate, especially laterally.

B. Size small, below 8 mm. Median depression of the anterior margin of the pronotum feeble, transversely wrinkled. Color "claire." Width of the head, including eyes, a little less than half the width of the pronotum behind. Eyes converging in front. Length, 7.2 mm.; width, 4.5 mm. *A. californicus.*

BB. Size larger, above 9 mm. in length.

C. Anterior margin of pronotum very visibly "rebordé" (with a visible ledge) behind the eyes; depression of the middle of the anterior margin transversely wrinkled and punctate between the wrinkles; interocular portion of the head narrowed in front; head with a very feeble longitudinal depression forming a median furrow, plainer behind. Length, 11.8 mm; width, 6.7 mm. *A. melanopterus.*

CC. Anterior margin of pronotum not or slightly visibly ledged (bordered) and then only in the middle.

D. Anterior angles of pronotum very prominent, sharp.

E. Average size larger (9.3 to 10.6 mm.); lateral sides of pronotum more dilated and more strongly arcuate without, dilation of embolium more pronounced. Coloration pale. *A. mormon.*

EE. Average size smaller (8.6 to 10 mm.); lateral sides of pronotum less dilated and less strongly arcuate without; dilation of embolium less pronounced. Coloration deeper. *A. heidemanni*

DD. Anterior angles of pronotum less prominent, almost right angles, scarcely pointed.

E. Head narrow, as long as the width of the interocular space behind; length of the head and pronotum together a little greater than half the greatest width of the pronotum. *A. puncticollis.*

EE. Head wide, length of the head and pronotum together equal to or a little less than half the greatest width of the pronotum. Pronotum

KEY TO AMBRYSUS—*concluded.*

equal to or imperceptibly longer than the head on its median line.

F. Eyes very convergent toward front on almost their entire length, width of interocular space in the middle subequal to the length of the head, much narrower toward the front. Color deep. Length, 13.3 mm.; width 8.3 mm.

A. guttatipennis.

FF. Inner edges of eyes subparallel or very feebly convergent toward the back, scarcely converging toward the front, only on the anterior third. Interocular space, even in front, wider or subequal to the median length of the head. Color, clear yellowish, flecked with brown. Length, 13.7 mm.; width, 8.8 mm.

A. signoreti.

Genus AMBRYSUS Stal.

Ambrysus pulchellus. Montd. 1897.

Mont. Verb. Zoöl. Bot. Ges. Wien., XXVII, pp. 11, 16.

"At first sight a little similar to *A pudicus* Stal. as to size and color, but proportionately a little less narrow; less narrowed behind; the small brownish spots a little more marked on the head and the pronotum, which is not punctate on the margins, and without depressions or wrinkles on the middle of the anterior border of the pronotum. The pronotum very little enlarged behind, the lateral margins almost parallel posteriorly. With almost no transverse furrow; very feebly marked on the margins. The posterior part behind the furrow pale, quite smooth, but covered by a few inconspicuous, very tiny black points. The head very notably punctate on each side near the eyes, these much larger proportionately than in *A. pudicus* Stal, as wide with the eyes as half the width of the pronotum. Scutellum and elytra of a uniformly deep brown without spots or clear areas except the embolium, which is yellowish on the basal ¾ for its entire width, the apical ¼ brownish. Margin of elytra is very slightly sinuate behind the embolium. Commissure of the clavus a little less than half the length of the scutellum. Connexivum yellowish with a slight amber band covering the tips and the bases of the segments. Posterior angles of the segments not prominent. Length, 8 mm.; width, 4.8 mm. Texas."

Ambrysus pulchellus Montd. 1897.

Var. *pallidulus* Nov. var.

"Length, 8 to 9 mm. Differs from the type by the complete absence of blackish spots or clouds. The head and pronotum entirely yellow, pale, immaculate, smooth, shining, save some very superficial impressed points, rare and little visible, near the anterior angle of the pronotum and behind the eyes. The scutellum entirely yellowish, sometimes scarcely a little less clear than the pronotum. Corium of a dirty yellow or slightly brownish, quite strongly narrowing behind the embolium, although without apparent sinuosity, and leaving largely uncovered the last segments of the connexivum, yellow, without spots or imperceptibly darker at their base. Posterior angles of the segments not protuberant.

"Texas, Belfrage U. S. N. M., Washington and my collection.

"This species in its form typical, of deeper color, is without any doubt very close to *A. nitidulus* Montand, 1909, of Mexico. However, the corium appear always sensibly less developed. and the punctation of the anterior angles of the pronotum less accentuated."

Ambrysus circumcinctus Montd.

Montandon, Bul. Soc. Sci. Bucarest, XIX, No. 3, p. 5, 1910.

"Form oval, hardly more attenuated in front than in the rear. Coloration dull uniformly yellowish on head and pronotum, a little infuscated on the scutellum and the elytra. Length, 8 mm.; head medium rather weak, with the eyes quite convergent in front for almost their entire length, the convergence a little less accentuated behind. Anterior border of the head quite regularly arcuated and very narrowly blackish at the tip, which margin is notably anterior to the level of the eyes. The head above, at least, as long as broad, between the eyes behind, about three times wider between the internal posterior angles of the eyes than the width of the eye at the same level; posterior portion of the head sunken into the median incisure of the pronotum, visibly longer than the anterior portion behind the eyes; punctuation of the head very fine, rather dense, but irregular and inconspicuous. Hardly a little more accentuated near the eyes and in front. Vertex uniformly pale without apparent markings.

"Pronctum with lateral margins feebly but rather regularly arcuated and divergent behind for almost their entire length, save in region of the posterior angles where they are narrowly subparallel. The angles are almost right, or a little obtuse, and slightly rounded at the summit. The lateral margins are very narrowly blackish on their extreme lateral margin. Anterior angles of pronctum rather acute but not arcuate at the summit. Anterior margin of pronotum profoundly incised. The transverse median incisure is rather large, but quite profound, the lateral incisures well accentuated behind the e es. They are, however, a little less transverse than in *A. pulchellus*. The entire surface of pronotum rather uniformly yellowish, hardly paler on the narrow posterior portion, a little depressed but without an apparent furrow, the depression almost lacking in the middle. Punctuation very fine, rather dense and irregular over the entire surface. Median sinuosity bordered by a weak margin less accenuated and with very fine and superficial transverse wrinkles, that are not very visible, behind the middle of the anterior border without apparent depressions, although this median portion may be visibly limited on each side by a slightly depressed oblique line, irregular, appearing a little 'posselee.'

"Scutellum slightly and rather uniformly darkened, with the basal angles and the summit paler, unpolished with the surface very finely granulated.

"Corium quite uniformly pale brownish, having the scutellum and embolium in large part pale, the external margin very narrowly blackish, slightly arcuated; margin of corium behind the embolium very obtusely sinuated. Commissure of the clavus narrowly pale, near the middle shorter than the length of the scutellum; posterior margin of the corium with a semi-circular yellowish spot. Disc of the corium appearing covered by a very fine pubescence almost clear. Membrane brownish concolorous with the corium.

"Segments of connexivum plainly visible behind the narrow elytral margin; unpolished, yellowish, without spots on the sutures, but with the extreme outer margin very narrowly blackish; posterior angles of the segments not projecting, following well the abdominal curve except on the last segment, whose angle is a little prolonged behind, but scarcely acute at the tip on each side of the female genital pieces.

"Body underneath yellowish ochreous, unpolished on the lower portion of the head, and the entire abdomen covered by a pubescence very dense and brilliant, almost golden. Legs pale, smooth, very brilliant. Labrum very obtusely angular in front, strongly punctured, yellowish with a strong brown tinge at the base; rostrum brownish, last segment darker. Texas."

A. mormon Montd.

Montandon, Bul. Soc. Sci. Bucarest, XVIII, No. 1, p. 48, 1909.

"Oval, more attenuate toward front than rear; color of a yellowish ochre, little brilliant; very finely granulate on the head and pronotum, dull on the scutellum and the corium.

"Head quite enlarged, a little narrower, eyes included, than half the greatest width of the pronotum, a little longer than the width of the intercular space, this latter very little convex, about three times wider than the width of the eye, pale yellowish with two brown spots subcontiguous at the middle of the base. These two spots sometimes join in front and are prolongated longitudinally in a narrow brown band, which attains almost the anterior margin of the head. Eyes convergent in front on their anterior half, the inner edges posteriorly subparallel; little enlarged.

"Pronotum deeply cut (scooped out) behind the head, this depression trisinuate, the median sinuosity behind the vertex larger and deeper, the two lateral sinuses narrower behind the eyes. Anterior angles of the pronotum sharp, lateral edges of the pronotum quite strongly arcuate with the posterior angle well rounded. Entire surface of the pronotum yellowish, paler on the posterior margin behind the transverse groove, quite plainly shown although very superficial and narrowly interrupted in the middle; this groove sometimes slightly blackish. Disk of the pronotum with six longitudinal, irregular, very poorly defined, little emphasized, brownish bands, the two median slightly forked in front, leaving between them a clearer space, bipunctate on the posterior part of the disk; two others bent narrowly behind, one on each side behind the eyes, attaining the middle of the disk, and two lateral ones, one on each side bounding the inner part of the margin; these brownish bands, for the rest, slightly visible, are without doubt very variable.

"Scutellum clear brownish, with the lateral edges close to the basal angles, and the apex pale.

"Corium clear brownish like the scutellum with the external border of the embolium strongly arcuate, yellowish on the anterior two-thirds, more or less abundantly (largely) brownish on the inner edge and at the extremity; margin of the corium very obtusely sinuate, narrowing very sensibly the corium behind the embolium where it leaves the abdominal segments well exposed, these latter yellowish with the posterior external angle of each segment strongly acuminate in a sharp, rather long point directed backwards. Membrane brown like the corium.

"Under side of body pale yellowish, slightly ochraceous on the breast (sternum), sometimes slightly darker on the abdomen, the latter entirely pubescent velvety save the narrow band of the connexivum, which remains smooth. Legs pale yellowish with the extremity of the tibiæ and tarsi narrowly and feebly darker. Length, 9.3 to 10.6 mm.; width, 5.8 to 6.2 mm. Utah." Also reported from New Mexico.

Ambrysus signoreti Stal. 1862.

Stal., Stet. Ent. Zeit., XXIII, p. 460.

"Larger and broader than in the other species; length, 13.7 mm.; width, 8.8 mm.; coloration clear yellowish, with a great brown blotch on the elytra, which gives it a very easily recognized appearance at first sight. The clavus pale yellowish, with a small brown blotch toward the base and another toward the tip. Elytral margin is obtusely sinuate behind the embolium, this latter very broad, yellowish throughout its

width on the basal ¾; brownish on the apical ¼; segments of connexivum brown on basal portion, yellowish behind. Transverse furrow of pronotum very plain, but somewhat superficial and a little interrupted at the middle; that portion of the pronotum behind the furrow very pale, smooth, having the punctuation very fine, concolorous and not dense." Reported from Colorado, New Mexico, Arizona and California.

Ambrysus guttatipennis Stal. 1876.

Stal., Enum. Hemip., V, p. 143.

"Length, 13.3 mm.; width, 8.3 mm.; having the elytra darker brownish than *A. signoreti,* Stal., having a small discal spot and a longitudinally elongated point at the middle of the corium yellowish; embolium yellowish on its entire width and on its basal two-thirds; brown on apical portion; entire clavus brown except on the commissure where it is narrowly yellowish; elytral margin behind the embolium obtusely sinuate; segments of connexivum brownish on the basal portion, yellowish behind; transverse furrow on the pronotum almost lacking; posterior portion of pronotum behind the furrow pale, finely scraped longitudinally, the scrapings well visible, less so on the posterior margin where the punctuation is very fine, concolorous and very dense throughout, or scrapings lacking." Found in Arizona.

Ambrysus puncticollis Stal. 1876.

Stal., Enum. Hemip., V, p. 143.

"Proportionately more slender than *A signoreti* or *A guttatipennis.* It is 13.7 mm. long and 8.2 mm. broad. Elytra and clavus entirely and uniformly darkened, having the commissure of the clavus narrowly yellowish and the embolium yellowish for its entire width on its basal half, and brownish on the posterior half, except a narrow yellowish border on the margin. Embolium less dilated than on the two species cited above; the external border of the elytra is not sinuate behind the embolium. The segments have the connexivum entirely yellowish, remarkable for the very acute teeth prolonged behind from the posterior angle of each segment. The transverse furrow of the pronotum is well marked, the posterior part behind the furrow pale, smooth, without apparent scrapings. Punctuation very fine and scarce but spread into very small rather dense black points." Found in Texas and Arizona.

Ambrysus melanopterus Stal. 1862.

Stal., Stet. Ent. Zeit., XXIII, p. 460.

"Size, 11.8 mm. long; 6.7 mm. wide. A little smaller than *signoreti, guttatipennis,* and *puncticollis,* but differs notably from these further by the darker coloration on the pronotum, except a narrow clear band on the posterior portion by its less enlarged form and subparallel lateral margins; lateral margins of pronotum strongly arcuated and in front are as subparallel as their posterior portion; that is to say, the pronotum is not entirely narrowed in front on its entire length, the posterior angles are right angles, a little subrounded above. The head is smaller proportionately than in the preceding species cited, the width of the pronotum being proportionately equal in width, including the eyes, to that part of the width of the pronotum near it and the length a little longer than the width of the eyes behind. The latter are very convergent in front for their entire length, surface of head and pronotum punctured, with a small groove at the middle of the base of the head, having the appearance of an anterior prolongation of the longitudinal furrow. The body beneath and the legs are also less clear, yellowish brown." Found in Texas and Arizona.

Ambrysus californicus Montd. 1897.

Mont., Verh. Zoöl. Bot. Ges. Wien., XXVII, pp. 12-18.

"Form oval, head yellowish ochre, as long as wide between the eyes behind; interocular space with the lateral sides subparallel on the posterior half, progressively narrowed in front on the anterior half. Its width behind is equal to three times the transverse diameter of the eye on the same level. Surface of the head very finely punctured, the punctuation a little less strong near the eyes. Vertex nearly smooth, finely rugulose, with the traditional spot of the genus a little broadened; very attenuated in front, "divided" at mid length, brownish, but very vaguely, poorly defined.

"Pronotum a little longer than the head on the median line. The anterior angle almost right angles, a little acute, not acuminate. The lateral margins feebly arcuated, divergent behind on their entire length; posterior lateral angles broadly rounded. Transverse furrow very plain, sunken, quite strong on the margin, narrowly interrupted on the median line; the punctuation fine and dense on the whole surface, a little more accentuated on the two anterior parts of the lateral margin. The anterior margin, which appears finely bordered between the eyes, is marked also behind the middle by fine transverse wrinkles that are rather crowded. The margin yellowish ochreous, rather broad; the disc and interior portion a little darkened, by the dots and small brownish blotches appearing poorly defined, the two median longitudinal ones a little more visible, arcuated, converging in front and behind, but not confluent, allowing between them a pale median line, unspotted, narrowed in front, and behind, broadened a little beyond the middle. In front reaching the anterior narrow black border, and behind reaching the transverse furrow; the portion behind the furrow very pale yellowish, unspotted, finely and densely punctured. 'Scraped off' on a narrow margin, the length of the posterior border of the pronotum.

"Scutellum yellowish brown, finely and densely punctured with the wrinkles very visible, little regular, and a little reticulated in places, especially toward the base. The principal wrinkle occupies the mid-length of the posterior half of the scutellum and is cut across a little before the summit by another transverse wrinkle.

"Elytra very finely and densely punctulate, granulate, of a yellowish brown, quite uniform, with the margin of embolium clearer yellowish. Commissure of the clavus a little longer than the middle of the length of the scutellum. Membrane brownish, a little darker than the elytra. Connexivum yellowish brownish, a little darker on a narrow band covering the sutures; posterior angles of the segments almost right angles, very feebly acuminate, and not prominent.

"Labrum very small, transverse, subrounded in front. Rostrum brownish, darker at extremity. Under the body a large part uniformly brown, legs yellowish, the femora paler than the tibiæ; length, 7.2 mm.; width, 4.5 mm." Taken in California, as the name would imply.

Ambrysus pudicus Stal. 1862.

Stal., Stet. Ent. Zeit., XXIII, p. 460.

"Head and pronotum smooth; the latter with the sunken points scattered on the sides. Rather strong transverse wrinkles covering the slight depression at the middle of the anterior border of the pronotum. yellowish 'a dessins' the brown points less marked on the head and pronotum; the transverse furrow on the pronotum well marked, the color clearer on the smooth region behind the transverse furrow. The pronotum very much widened behind, having the lateral margins very convergent for almost their entire length. Postero-lateral angle quite broadly subtruncate, a little rounded. Eyes also quite strongly convergent for almost their entire length. The length of the head is much

less than width. The interocular space behind and its width, including the eyes, is very much less than half of the very large pronotum.

'Elytra clear brownish, a little darker on the middle of the disc. A small yellowish point on the middle of the posterior border of the elytra. Embolium yellow in all its width on the basal ¾, brown at the extremity; elytral margin behind the embolium imperceptibly sinuate, commissure of clavus a half shorter than the length of the scutellum; connexivum yellowish, hardly and very narrowly browned in the sutures of the segments, with the posterior angles little prominent behind. Length, 7.7 mm. to 8 mm.; width, 4.8 to 5.2 mm. Mexico, Wyoming, California."

Ambrysus heidemanni Montd.

Montandon, Bul. Soc. Sci. Bucarest, 1910, XVIII, p. 188.

"Species very close as to form, mode of construction and design to *A. mormon* Montand, differing from it only in the size, a little more feeble. 8.6 to 10 mm.; in the lateral sides of the pronotum less dilated and less strongly arcuate without, as well as the dilation of the embolium a little less pronounced, the spines of the posterior angles of the segments of the connexivum a little less strong and less projecting although always plainly visible, and in its deeper color, in design identical but more extended, sometimes nearly black on the head and pronotum; the scutellum and corium uniformly more or less deeply brown, with the margin of the embolium quite largely pale, poorly limited on its inner edge, the basal angles and the apex of the scutellum pale; the segments of the connexivum marked by a transverse black band covering up their basal thirds.

"The longitudinal median black band of the head quite enlarged, not reaching clear to the anterior border, but behind, it sometimes extends on all of the posterior part of the head from one eye to the other on a level with the posterior angles of the eyes.

"Yellowstone Park in the puddles of water of the geysers. It is to the kindness of Mr. Otto Heideman, the learned American Hemipterologist, that I owe this species which has enriched my collection. I have also found a very dark specimen from the same locality in the material of the National Museum at Washington.

"The darker posterior part of the vertex is more often marked by a median yellowish spot. The black blotches of the pronotum frequently form two more or less triangular figures on each side, these very unequal figures sometimes united, sometimes very vague, with only the contours indicated in places, but recalling always the same design as in *A. mormon* Montand., and always much less emphasized with deeper color.

"The margins of the pronotum as also the posterior border always clear, the latter quite straight, and marked sometimes by irregular blackish spots." Taken in Wyoming.

Genus PELOCORIS, Stal. 1876.

Stal, Enum. Hemip., V, pp. 142-144.

These bugs do not have the head so deeply set into the prothorax as the members of *Ambrysus*. Beak is very short. Posterior tarsi shorter than posterior tibiæ. The latter outside and inside equally broad. Inferior side narrow, scarcely oblique. Eyes converging anteriorly, inner margin distinctly sinuated. Anterior angles of pronotum extending to the middle of the eyes.

KEY TO SPECIES OF PELOCORIS.

A. Ventral plate of the female genital segment "cleft" or emarginate at tip. Prothorax stout, densely punctate. (Length, 8.2 to 9.6 mm.). *P. carolinensis.*

AA. Ventral plate of female genital segment not emarginate at tip. Prothorax less densely punctate. (Length, 9 to 11.5 mm.)

B. A dark streak on embolium, scutellum dark. *P. biimpressus.*

BB. Not as above. *P. femoratus.*

Pelocoris carolinensis Bueno, 1907.

Bueno, Can. Ent., XXXIX, p. 227.

"Head: Broader, including eyes, than long; front more or less remotely punctuated and furrowed; width at base and at widest part subequal; eyes longer than wide, greatest width about one-third from the distal end; sinuate in the inner margin, converging toward the distal end more than toward the proximal end. Labrum broader at base than long; triangular in shape, with rounded apex attaining the middle of the third segment of the rostrum. Rostrum short, stout.

"Pronotum about 2⅓ times as broad as long along the median line; broader at base than at distal margin; both basal and distal margins more or less sinuate; edges curved regularly from the eyes to the humeral angles, which are rounded; disc with indented lines behind the head, parallel to the anterior margin, the first line as long as the distance between the eyes, and diminishing in length posteriorly, giving an obtusely triangular shape to the lined area, the remainder of the disk coarsely punctuated, caudad of the pronotal suture it is shagreened in wavy lines.

"Scutellum about twice as long along the medial line; apex blunt; sides sinuate, shagreened.

"Hemelytra narrower than abdomen, but extending to end of same. Membrane distinct, but merging insensibly into the corium. Embolium flattened and broadened marginally, extending beyond the abdomen. The three last connexival segments have prominent posterior angles. Entire hemelytra, including the membrane, covered with very short, sparse golden hairs. Mesosternal keel slightly raised, grooved longitudinally with hairs arising on either side, and nearly covering the groove.

"Abdomen: Genital segments prominent in male, flattened and cleft in female. These segments are somewhat complicated, and no adequate description can be made without a dissection.

"Pedes: First pair raptorial, with incrassate femora grooved for the reception of the tibiæ, which are curved and furnished with a one-jointed tarsus, destitute of claws. Second and third pair cursorial, with normal femora and tibiæ, with two-jointed tarsi, armed with moderately long, slender claws. The tibiæ are furnished with moderately long spines in two rows.

"Coloration: Head flavous, with a dark median line of varying width, sometimes reduced to a triangle at the vertex, and at others entirely absent or very faint. Prothorax also flavous, the punctuations of the disk brown, the flattened outer margin much lighter in color; the area caudad of the suture, more or less variegated with perpendicular black lines of varying widths. Scutellum brown, the apex sometimes lighter in color, approaching to flavous; some individuals have lighter vermiculations in the disk. Hemelytra also brown, with lighter vermiculations, the ground color of varying shades; the darker forms have two flavous spots on the corium at the edge next to the membrane, which disappear in the lighter forms. The embolium is testaceous, darkening caudad. The connexival segments are black posteriorly. The abdomen varies from testaceous to dark brown. The legs are concolorous except the spines, which are darker and black-tipped; the anterior legs are flavous, except the apex of the tarsus, which is dark. Labrum flavous; terminal segment of rostrum darker at the lip.

"Measurements: Head—long., 1.5 to 1.7 mm.; lat., 2.6 to 2.9 mm.; long., 1.8 to 1.9 mm.; lat., 2.8 to 3 mm. Pronotum—long., 1.7 to 2 mm.;

lat., 4 to 4.6 mm.; long., 1.9 to 2mm.; lat. 4.5 to 4.7 mm. Scutellum—long. (measured from prothoracic groove), 1.3 to 1.4 mm.; lat., 2.3 to 2.7 mm.; long., 1.4 to 1.5 mm.; lat., 2.7 to 2.9 mm. Insect—long., 8.2 to 9.3 mm.; lat., 5 to 5.5 mm.; long., 9.3 to 9.6 mm.; lat., 5.6 to 6.1 mm." Kansas, North Carolina and South Carolina are localities from which this species has been taken.

Pelocoris biimpressus Montd. 1898.

Mont., Bul. Soc. Sci. Bucarest, VII, p. 285.

Montandon and Champion both mention this as a variety of the species *Pelocoris femorata*, as set forth in the key. Stal says it is from North America.

Pelocoris femorata, P. B.

Palisot Beauvoris, Ins. Rec. Afr. Am., p. 237.
(The following from Uhler, 1884.)

"Color more or less greenish testaceous. but after death it changes to a pale yellow, or horn brown. It has a black line across the base of the labrum; on the prothorax a dark brown quadrangular spot is seen on the middle next the front margin; each side of this is a wide triangle composed of scattered dots, flanked by larger and still more remote flecks, and with short, almost black lines in a series across the posterior submargin; while the lateral margins are broadly pale. The scutellum is rough, and almost covered by dark brown marbled lines. The slightly convex wing covers are livid brownish, with two pale dots inwardly next to the base of the membrane, and the base of the flat costal margin is broadly pale testaceous. On the venter is a faint trace of silky hair. the sides of the abdomen are marked with six squarish, black spots, and the legs are ivory white, or yellowish. The anterior tibiæ are strongly curved, tinged with piceous and there is a dot of the same color on the apex of the pairs of posterior tarsi. It measures a little more than one-third of an inch."

Distribution: "Mississippi, New York, New Jersey, Pennsylvania, Maryland, Florida, Illinois, Wisconsin, Minnesota, Michigan, Tennessee, Louisiana and Carolina."—*Van Duzee.*

B. Biology of Naucoridæ.

General Notes. These flattened oval bugs are found amidst tangled growths of *Nitella* and other water plants. They seem to abound where there is a good shelter of water plants to which they cling. They swim through the water with an even, rapid gait, and catch their prey, which may consist of insects cast upon the water or any aquatic insects it can capture and overcome.

Genus AMBRYSUS Stal.

Habitat. Uhler says that *Ambrysus signoreti* dwells in the quiet waters adjacent to streams and in standing pools, especially such as are grassy. Another species is found in ponds in Dakota. No one seems to have noted the eggs or other biological matters concerning these insects.

Genus PELOCORIS Stal.

This genus, related to the European *Naucoris* of literature, has been more frequently studied. The notes on the European forms date back to an early time. De Geer noted their swimming ability and stated that they fly at night; that they eat all sorts of little aquatic animals. Dufour described the eggs of two species, *N. cimicoides* and *N. maculata*. The

latter species he said he kept confined for a long time, and that they lay their eggs toward the last of April "en les collant contre des brins de plantes aquatiques." Regimbart, 1875, said that *N. cimicoides* buried its eggs in plant tissues.

Genus PELOCORIS Stal.

The members of this genus and its European relative *Naucoris* of literature, are better known than those of *Ambrysus*. Frisch, 1727, under "Von der breiteren Wasser Wanze" says it is predatory and can chirp. Roesel, 1746, says that "Die breit leibige schwarz braune Wasser Wanze mit dem gelb eingefassten hinter leib und derselben Fortpflanzung" had an egg like the back-swimmer, only more rounded, and that the adults in August overwintered. De Geer noted their food and nocturnal flights. More recently we have Kirkaldy's notes on *Ilycoris cimicoides* and Bueno's history of *Pelocoris femorata*.

Hibernation. As far as known all of these bugs winter as adults hidden in mud and trash. Uhler says that *Pelocoris femorata* hibernates at the bottom of pools and ponds, in places where it can find some depth of muck, and especially where reeds or water-plants remain rooted through the winter.

Oviposition Roesel, 1746, Dufour, 1833, and Kirkaldy, 1905, describe the eggs of the European form *cimicoides* as placing its eggs upon stems. Regembart, 1775, said it inserted them in tissues of plants. In support of Regembart, Wesenberg-Lund in "Fortpflanzungsverhaltnisse; Paarung und Eiablage der Suss wasserensekten" says: "In May, 1895, I found numerous eggs in the air spaces of leaves." Out in nature they were in old plant parts. From the ovipositor he thinks it is not likely that it just lays them on the plants.

The American *P. femorata*, Uhler, 1884, says, glues its eggs to the submerged leaves and sprays of plants. Bueno, 1903, also finds this to be the case. He says, "The majority have been found attached axially to the stems or leaves of Ceratophyllum and secured to them by a glue in which the ovum is set and which surrounds slender stem or leaf to a variable extent."

Incubation. Bueno has found the egg stage to last from 22 to 27 days. This was in early June.

Number of Nymphal Instars: Five.

Food Habits. The writer has fed them many different kinds of insects. They will also eat snails. Bueno fed his bugs one fly apiece each day.

Behavior. These bugs like the dense cover accorded by water plants. In a series of "holes" in an intermittent creek bed near Coldwater, Kan., *Naucoris carolinensis* was taken in great numbers. These pools were spring-fed, and overgrown with a "water moss" (Nitella). This collection was made July 28, by the party under Mr. Beamer's direction. The description of the waters is taken from the collector's field notes.

"The bottom was clay and sand, covered with 3 or 4 inches of soft, slimy mud, and above this was a great mass of moss. (Nitella.) We could not run the net through into it very far, but had good success pushing it into it as far as possible and then lifting and shaking the

mass above the net. After prodding among this material and getting stung by Naucorids until a retreat was necessary, we would take the material to the bank and work it over, taking dozens on the way."

The "sting" of this insect is indeed painful for a time, and it leaves a stinging, itching, burning sensation for some time, as the writer has found.

DESCRIPTION OF STAGES.

Pelocoris femoratus.

The following is taken from Bueno, 1903. The writer has reared *P. carolinensis* in part, but has never had the time to describe the material:

The Egg.

Size. "Length, 1.4 mm.; width, .6 mm.; altitude, .7 mm.

Shape. "From above, imperfectly oval; from the side somewhat flattened above, with a gradual rise toward the middle. The cephalic end is more rounded than the caudal, descending to the line of attachment with a shorter curve. This curve is somewhat depressed at the extremity of the ovum, from which depression arises the micropylar boss. The form changes during incubation and just previous to emergence the ovum is larger and rounder than when first deposited."

Color. "Translucent, pearly white when deposited, growing darker as development progresses. The surface is minutely punctulated in lines, punctures set close together, giving the appearance of meandering striations. As the time for emergence approaches, the character of the markings changes. The chorion is still punctulated, but at the same time engraved in distinct hexagons, produced by the punctulations."

First Instar.

Size. "Length, 2.5 mm.; width, 1.5 mm.

"Immediately after emerging from the ovum, the nymph is transparent, white and colorless, except that each abdominal segment has a broad, dark, luteous band at the connexivum. Also, the eyes are red and well-marked. The tarsal claws of the second and third pairs of pedes are dark and noticeable. The single claws of the first pair are colorless and transparent. The short rostrum is transparent pale luteous, darker at the tip. A seta issues from the posterior angle of each abdominal segment, at the connexivum, on the dorsal surface. About eight hours after emergence the insect is much darker in color.

"In shape the young *Pelocoris* resembles nothing so much as the suctorial midnight prowler, at a superficial glance. Carefully examined, however, it is seen to resemble closely the adult in shape, allowing for the difference in size and absence of wings.

"When recently hatched its abdominal air coating is absent, and the young insect finds it difficult to reach the surface, which it succeeds in doing only by vigorous swimming. If it relaxes its efforts, it immediately sinks to the bottom. *Pelocoris* swims back down when in this condition.

"When still uncolored, the dorsal vessel can be plainly seen pulsating and the oily globules of the unabsorbed yolk moving in the abdominal cavity."

Second Instar.

Size. "Length, 3.25 mm.; width, .2 mm.

"The appearance after the molt is practically the same as after emergence from the ovum, except that there is a dark, somewhat triangular-shaped blotch extending from the caudad margin of the thorax to the fourth abdominal segment, apparently produced by the abdominal con-

tents. The pulsations of the dorsal vessel can also be seen in this instar under the same conditions as before, save that the yolk is, of course, totally gone."

Third Instar.

Size. "Length, 4.8 mm.; width, 3 mm."

Fourth Instar.

Size. "Length, 6.5 mm.; width, 4.2 mm.

"Coloration and other peculiarities slightly more accentuated than in the preceding instars. I may here state that just previous to a molt the insect is very thick through, especially so in this and the succeeding instars, and looks fit to burst out of its skin, as it does."

Fifth Instar.

Size. "Length, 8.3 mm.; width, 5.5 mm.

"I was fortunate enough to have the opportunity of observing the last moult in *Pelocoris*, which I will now describe from my notes taken during the process of the ecdysis.

"The bug hangs from the surface, back up. The outer skin then splits along the thorax, and the scutellum of the emerging insect is seen. The opening enlarges as the insect gives rhythmical convulsive heaves. First the entire thorax comes out; then, with a jerk, the head. It now rests a moment, and in a short space again takes up its motion, withdrawing the body little by little from the cast-off skin. The dorsum, as yet uncovered by the still unexpanded alæ and hemelytra, has a coat of air. The wings and hemelytra expand as the insect emerges, so that by the time it is entirely out they are fully developed, completely concealing the dorsum abdominis. It takes the insect about ten minutes to go through this final transformation. When it is entirely free, it turns quickly and hangs back down from the air-filled and buoyant cast skin for a moment, until the wings are perfectly expanded. Then it begins to swim about quite rapidly, coming to a rest once more, seemingly requiring something to hang to. There appears to be an undue amount of air under the insect's wings while it is in this condition, and it remains back up while swimming. The tracheal lining may be seen as *Pelocoris* emerges, connecting the sternum with the cast skin.

"*Pelocoris*, immediately after the last ecdysis, is entirely of a beautiful light green-like aquamarine, including the hemelytra and the limbs excepting the tibiæ, which are dark from the swimming hairs. The eyes are a dark ruby-red. The insect gradually grows darker, and about four hours after the change it is a mottled dark green. The full mature coloration is reached in about 12 hours."

Summary. Bueno has presented the only account of the rearing of any Naucorid. The eggs of *Pelocoris femorata* were placed upon submerged plants. They hatched in about 24 days. The first instar lasts about 8 days; the second instar, 6 to 9 days; third instar, 8 days; fourth instar, 10 to 12 days; fifth instar, 16 days. A total, as Bueno tells us, of some 77 days for development. Nearly all stages may be taken in the summer time in a pool. At Coldwater, Kan., in July, all stages but the egg were noted.

Family *CORIXIDÆ*.

A. Taxonomy of Corixidæ.

Family Characteristics. These medium-sized to small bugs are usually marked with bars of yellow and brown. The body is flattened above, and the head overlaps the thorax dorsally. The most peculiar thing about them is the structure of the beak, which is very short, scarcely if at all

distinguishable from the face, the opening to the mouth being on the front of the so-called beak. The front tarsi are also peculiar, being 1-segmented, flattened and fringed with strong bristles. They are spoon-shaped, or palæform. The middle legs are long, slender, and end in two long claws. The hind legs are flattened and fringed for swimming.

Historical Review. "Corixa" means bug, and is a fitting name for these water bugs, for they have a buggy smell. They have been known by this name since Geoffrey, 1762. Borner, 1904, in a study of the mouth parts of this group, separated these bugs off as a separate suborder, *Sandaliorrhyncha.* The other suborders he called *Auchenorrhycha* (Homoptera), *Heteroptera* and *Conorrhyncha.* Bueno even gives them ordinal rank, but Reuter reduces the *Sandaliorrhyncha* to a series under the Heteroptera.

Key to Genera. Doctor Abbott, of Washington University, has been working for several years upon a world monograph of these bugs. He expected to complete the systematic part two years ago, but the interruptions of the times have kept him from so doing. It is a most difficult group, and it is to be hoped he can give the workers a practical means to determine their material.* For the present the writer gives a tentative key to the genera. He knows of too much synonomy to waste time on specific keys to the large genus *Arctocorixia,* which contains some fifty species, for instance. Only the males are keyed out satisfactorily. The females look much alike.

KEY TO GENERA OF CORIXIDÆ.

Males.

A. Scutellum covered by pronotum only at the anterior margin. Pronotum roundly emarginate behind. *Tenagobia* Bergroth.

AA. Scutellum covered (except sometimes at posterior angle) by pronotum.

B. Strigil absent. Pronotum and tegima more or less rastrate. Conspicuous black spot usually present on hind tarsi. *Callicorixa* White.

BB. Strigil present.

C. Strigil on left side. Pronotum and tegmina smooth, shining, asymmetry on left side. *Corixa Geoff.*

CC. Strigil on right side.

D. Head of male sharply acumiate. Asymmetry right. Strigil small. *Ramphocorixa* Abbott.

DD. Head of male normal.

E. Hind wings usually aborted. Palar pegs in two series, or one crowded row. *Palmocorixa* Abbott.

EE. Hind wings normal. Stridulatory palar pegs well developed, curved in single row. *Arctocorixa* Wallen.

* Doctor Abbott has now given up this work, and the writer has the task of completing Doctor Abbott's work. He is permitting the keys to stand for the present as first written.

Females.

A. Scutellum covered by pronotum only at the anterior margin. Pronotum roundly emarginate behind. *Tenagobia.*

AA. Scutellum covered (except sometimes at posterior angle) by pronotum.

B. Face flattened, foveate, palæ deeply furrowed. *Ramphocorixa.*

BB. Face convex.

C. Hind wings aborted usually. *Palmacorixa.*

CC. Hind wings normal.

D. Pronotum and tegmina smooth, shining. *Corixa.*

DD. Pronotum and tegmina not smooth and shining.

E. Hind tarsi pale, fringing hairs dark in some species. *Arctocorixa.*

EE. Hind tarsi usually marked by conspicuous black spot. *Callicorixa.*

Genus TENAGOBIA Bergroth 1899.

Minute species never over 5 mm. long. The scutellum is covered by the pronotum only at the anterior margin, and the pronotum is roundly emarginate behind. One species, Pacific.

Genus CALLICORIXA White 1873.

Three species of bugs, all from Alaska, are in our list. The scutellum is covered, except sometimes at the posterior angles by pronotum. Strigil is absent. A stridular area is present. The hind tarsi usually marked conspicuously with black. Three species, all from Alaska.

Genus CORIXA Geoffrey 1762.

Pronotum and tegmina are smooth and shining. The male asymmetry is on left side. Strigil is present. Scutellum is covered (except sometimes at posterior end) by pronotum. Palar stridulator never with bristles, although the "pegs" may be elongate.

Genus RAMPHOCORIXA Abbott 1912.

Peculiar in the sexual dimorphism of the head, the male very acuminate, the female normal. See plate XXVII. The asymmetry is right and strigil minute. The pronotum is lenticular rastrate. The male palæ are dorsally deeply cleft, much longer than tibiæ, and terminated by a long serrated spine. Femur with large stridular area or of minute spines. Face of the female foveate.

Genus PALMOCORIXA Abbott 1912.

"Body elongate, tegmina tapered posteriorly, with vermiculate markings. Male palæ thin, plate-like, pegs variable. Large stridular area on femur. Metathoracic wings aborted in both sexes (usually*). Male

* The writer's insertion.

asymmetry and strigil dextral; fifth tergite entire, sixth divided."—*Abbott.*

The above description is taken from Can. Ent. for April, 1913. This is a revision of the original generic diagnosis. To date there have been described two species separated by the following table.

KEY TO SPECIES.

A. General facies dark. Tegminal lineations complete. Front femur of female oblong, 2½ times as long as wide. Palar pegs of male 24-33* in crowded row the length of pala. *P. buenoi* Abb.

AA. General facies light. Tegminal lineations incomplete. Front femur of female trapezoidal, two-thirds as wide as long. Palar pegs of male in two rows confined to base of pala. *P. gillettii* Abb.

Palmacorixa buenoi Abbott.

Can. Ent., Apr. 1913.

"Similar to *P gillettei* in size and appearance, in the flattened short pronotum, and large head, with prominent posterior angles. Dark yellow to smoky brown, and much darker than *gillettei.* The tegminal lineations are complete, more or less inosculated and confused, but without a marked tendency to longitudinal seriation. Lineations of clavus complete, *i. e.*, not effaced on the inner anterior area as in *gillettei.* Head smoky brown; its length 1¾ in the width of the male, 2¼ in the female; interorbital width twice in the head length in the male, 1¼ in the female. Male fovea more prominent than in *gillettei*, reaching the middle of the eye, and clothed with delicate depressed hairs. Pronotum flattened, margined, lenticular in outline, evenly rounded posteriorly, dull and minutely rastrate, with 7/8 approximately parallel lineations, which are more or less broken, the lineations about as wide as the yellow interspaces. Posterior margin brown. Claval lineations delicate, vermiculate and inosculate, covering the whole clavus, fused externally to form a more or less definite oblique line parallel to the corio-claval suture. Clavus rather infuscated and clouded across the middle third. Markings of corium similar to those of clavus, running without interruption over the membrane; inosculated, but scarcely interrupted, sometimes fused into one or two rather indefinite longitudinal lines, which do not extend beyond the embolium. Surface of clavus and corium rather dull and rough, the clavus usually rastrate, the corium merely punctate. Margins of embolium and of clavus elevated. Lower surface and legs pale; posterior tibia fringed with brown hairs. Metaxyphus very short, acuminate. Strigil rounded, 5 striæ, diameter 0.1 mm.

"Male palæ cultrate, somewhat produced at the base, the length three times the greatest height. Pegs blunt, elongate, 24-33 in number. The distal ones are somewhat longer and crowded, and may be displaced into two irregular rows. The main row begins midway the base and rises in a curve after the first half dozen pegs; then follows the upper margin, but at some distance from it. A second row of peg-like spines along the lower margin, about 1½ to 2 times the length of the pegs. Tibia subglobular, about as high as the pala. Femur oblong, a little less than twice as long as wide, the stridular area covering the proximal half and consisting of short spines set in transverse rows. Female palæ cultrate, not produced at base, slightly more than three times as long as wide, broadly joined to the tibia. Tibia rounded oblong, tapered proximally, twice as long as high. Femur oblong, 2½ times as long as wide (the width at base in *P gillettei* is two-thirds the length) with stridular spines* on the surface as in *P. gillettei.* Second leg, Femur 2½ times

* Number of pegs exceeds this in one series examined by the writer.

* Through a *lapsus calami* these are called "spines" in the description of *P. gillettii* (l. c., p. 339).

the length of the tibia, the latter equal to the claws, and 1⅓ the length of the tarsus. Length 5½ to 6 mm.; width across pronotum 1½ mm.

"Types 2 (male) and 2 (female), from White Plains, N. Y., collected in August and September by J. R. de la T. Bueno. Other specimens have been examined from Washington, D. C. (coll. W. L. McAtee) Oglethorpe, Ga. (coll. T. C. Bradley) Hadley, Mass., (coll. C. A. Frost) and Valhalla, N. Y. (coll. Bueno). The species, therefore, appears to be distributed pretty widely up and down the Atlantic coast of the United States.

"*Variation.* Some twenty specimens have been examined in addition to the described types. These individuals show a wide range of variation, such that the extremes would seem to belong to different species were it not for the intergradation. The writer has been unable to find any constant character, however, which would serve as a basis for discrimination. The smallest (White Plains) measures but 4¼ mm., the largest (same locality) 6½ mm. The tegminal surface may be smooth and polished, or dull and rastrate, the lineations varying from the regular complete lines of the type to interrupted and confused markings, resembling those of *P. gillettei;* the inner angle of the clavus, however, is never bare of lineations. Pronotal lines 6-9, either entire or much broken and confused. The index of pronotal width divided by pronotal length ranges from 2.22 to 2.60 in the ♀, and 1.79 to 2.73 in the ♂; that of the head width divided by the interorbital width ranges from 2.87 to 3.57 in the ♀ and from 3.60 to 4.20 in the ♂; that of the head width divided by the head length from 2.07 to 2.60 in the ♀ and from 1.68 to 2.33 in the ♂. In the male the palar pegs are sometimes crowded into two rows at both ends of the series. The absence of functional wings in both sexes in this genus certainly interferes with the rapid dispersal or mixing of individuals from adjacent localities, and thus brings about a partial segregation which would preserve and intensify aberrant variations. This possibly explains the very unusual range of variability above described."

Palmacorixa gillettii Abbott.

Ento. News, Vol. XXIII, p. 337, Oct. 1912.

"Head pale yellow, vertex usually carinate, posterior angles rather acute and produced backward. Posterior margin emarginate. Interorbital space (posterior margin) about twice in the median length of the head in the male; one and a half times in the female. Inner margins of eyes parallel in facial aspect.

"Pronotum lenticular, with a more or less definite median keel, rather strongly margined, the margin being marked by a narrow line of brown, the anterior line incised to correspond with the emargination of the head. Color, yellowish, paler at the sides, with eight to ten delicate broken and confluent lineations, some of the most posterior of which join the marginal line. Surface of pronotum polished, minutely rastrate; it requires a compound microscope to resolve the rastrations.

"Tegmina polished, nonrastrate, light yellowish with brown markings. The latter are quite variable, usually not displaying the familiar cross-barred effect of the majority of the species in the family. Clavus more or less immaculate toward the inner angle as in *mercenaria* Say, the markings reduced to a more or less definite diagonal stripe following the direction of the corial suture. The inner edge of the clavus is margined with brown, and between this and the diagonal stripe mentioned are numerous lineations, ranging from isolated flecks in some individuals to interlocking and cross bars in others. Embolium immaculate, its inner edge strongly margined. Corium and membrane with vermiculate and inosculate brown markings, usually arranged in two rather indefinite longitudinal stripes. A dark fleck on the outer edge of the membrane.

"Metathoracic wings aborted in both sexes to a rudiment which ex-

tends from thorax to about the level of the third abdominal segment. Strigil ovate, about 0.3 mm. long, by 0.2 mm. wide, transversely placed, with 6 to 7 striæ. Legs and entire under surface yellowish white.

"Male palæ very strongly compressed, plate like, the lower edge straight, the upper edge parabolic in outline; the surface covered with fine depressed spines. Toward the lower edge, next the tibial joint, are found the "pegs" in two rows, 5-6 in the upper row, 9-10 in the lower. These two rows seem rather sharply differentiated from the rest of the spines covering the face of the pala, yet it would seem to be not impossible that the whole surface may function in stridulation. The lower edge of the pala is fringed, but there is no terminal spine. Tibia globular, about one-fourth the length of the pala. Femur oblong, as long as the pala, its width about one-half its length. Stridular area large, consisting of numerous rows of minute spines. Female palæ short cultrate, triangular in section, the length a little less than three times the greatest height. Tibia rounded oblong, about as wide as the pala, its length a little more than twice its width. Femur trapezoidal in shape with a distinct area of strong spines analogous to the stridular area in males.

"Second leg: Spines about equal to tibia in length, the latter one-half the femur. Tarsus slightly shorter than tibia. Third legs: Femur and tibia subequal and about four-fifths the tarsus. Metaxyphus short, acute.

"Length, 6 mm.; width across pronotum, 1½ mm.

"Described from three males and three females from Fort Collins, Colo., collected in May and June by Prof. C. P. Gillette, to whom the author is indebted for the specimens. Superficially the species resembles *calva* Say, with which it possibly has been confused. It is considerably larger than Say's species and structurally very different from any other Corixid with which the writer is familiar."

Genus ARCTOCORIXA Wallen 1894.

The scutellum is covered except sometimes at posterior angles by pronotum. Tegmina without short black hairs. Asymmetry on right side. Palor stridulator never with bristles although the pegs may be elongate. Strigil present.

B. Biology of Corixidæ.

General Notes. The water boatmen spend most of their time upon the bottom of the pool, where they feed upon the flocculent deposits of ooze containing diatoms, desmids, filamentous algæ, oligochetes, etc. This food they gather with their front legs. They fasten their yellow top-shaped eggs to submerged brush or vegetation. One species places its eggs upon crayfish. The adult males chirp by rubbing the front tarsi against the beak or the femur of opposite leg.

The writer submits herewith notes on but three species. He has reared a considerable number, but intends to report upon them in an extended monograph of the Corixidæ now in preparation. The three species chosen represent three genera and illustrate the diversity of habits in the group.

Ramphocorixa acuminata Uhl.

Doctor Abbott has written two papers on the biology of this species, one dealing with the manner of its oviposition and the other some notes on the life history, together with a description of the instars. It is indeed a remarkable form and Doctor Abbott described it as a new genus and new species when it came to his hand. He has since decided that it is the same as *Arctocorixa acuminata* Uhl., though the bug is much more

readily recognized by Abbott's description and figures. The dimorphism of the sexes is perhaps the most remarkable in the entire family, the head of the male being decidedly acuminate, while that of the female is normal. See figs. 2 and 3 on plate XXVIII.

Habitat. This form is found in the muddiest of ponds in the middle west. No waters appear to be too stagnant for its abode, which may account for its strange habit of placing its eggs upon the carapace of crayfish.

Hibernation. Females of this species have been taken by the writer in Kansas in winter collecting.

Mating. Mating takes place in the same manner as with other Corixids and at about the same time.

Oviposition. In a paper entitled "An Unusual Symbiotic Relation between a Water Bug and a Crayfish," Doctor Abbott gives an interesting account of the strange habits of egg deposition of this species. The paper is accompanied by two photographs of crayfish laden with Corixid eggs. He describes the condition very accurately, noting that the reception of each egg cup, "as if the affixing of the egg had either softened the chitin somewhat, or had taken place before the hardening subsequent to ecdysis had been completed."

Forbes, in 1876, seems to have been the first to note that crayfish carry Corixid eggs. He suggested that they were probably the eggs of *Corixa alternata* Say, but since we know the habits of both species in question, it was without doubt Abbott's *Ramphocorixa balanodis.* While both Doctor Abbott and Doctor Forbes failed to find these eggs anywhere else in the water, the writer has occasionally found them attached to sticks and floating plants, but never in numbers. There is indeed a striking intimacy between these animals. Doctor Abbott attempts to explain the "symbiosis" as follows:

> "The investiture of eggs commingled with debris certainly renders the crayfish less conspicuous and it probably profits by the arrangement in much the same way as do various shore crabs which are decorated with sponges, algæ or coelenterates. Whether the water bug improves its chances against racial extermination by the adoption of such a pugnacious protector it may be too much to assume, but at any rate, whatever the utilitarian value of the habit, it must be of the same nature as that which obtains in the widely distributed genus *Zaitha.*"

In a study of a considerable series of crayfish carrying various numbers of eggs, the writer believes he has found a plausible explanation for the unique support employed by this Corixid. A casual examination of many *Cambarus immunis*, together with the tabulation of the distribution of eggs upon a representative series, herewith represented, leads to the belief that it is a matter of aëration.

An examination of the table shows that there was a marked tendency for the first eggs to be placed low on the pleurites of the first abdominal segment. That, after many eggs were thus deposited, they were placed upon the carapace near the lower posterior margin. In one case, number 5, there were 13 eggs on top of the carapace behind the eyes.

When we study the respiration of the crayfish we find that a current

EGG DISTRIBUTION UPON THE CRAYFISH.

Crayfish No.	Length crayfish in inches	Sex of crayfish	Carapace.						First abdominal segment.						Second abdominal segment.						Third abdominal segment.						Fourth abdominal segment.					
			Top.		Right side.		Left side.		Top.		Right pleurite.		Left pleurite.		Top.		Right pleurite.		Left pleurite.		Top.		Right pleurite.		Left pleurite.		Top.		Right pleurite.		Left pleurite.	
			No. eggs	Place	No. eggs	Place	No. eggs	Place	No. eggs	Place	No. eggs	Place	No. eggs	Place	No. eggs	Place	No. eggs	Place	No. eggs	Place	No. eggs	Place	No. eggs	Place	No. eggs	Place	No. eggs	Place	No. eggs	Place	No. eggs	Place
1	2												4	L					4	L												
2	2¼				38	LPM					37	L	50	L			6	L	2	L			3	L	2	L						
3	2										9	L	2	L			1															
4	1¼						62	PM			21	L	59	L			2	L	4	L			2	L								
5	2¼		13		3		4				44	L	31	L																		
6	2½												1	L																		
7	2																															
8	2¼										6	L	6	L																		
9	2¼										27	L	7	L																		
10	2¼										4	L																				
11	2										8	L	13	L																		
12	2				2	LPM	4	PM			12	L	9	L																		

L—Low on pleurite. PM—Posterior margin. LPM—Lower posterior margin.

of water is kept passing beneath the carapace and over the gills. This water enters the gill chamber from the rear, passing directly by the abdominal pleurites. The current would be strongest at the first abdominal pleurite, and it is just here that we find the first eggs. Figure 1, plate XXVIII, attempts to illustrate this point. The eggs, therefore, are placed upon the crayfish in the region where there are the best chances for aëration.

If only crayfish heavily burdened were examined, it would not be so apparent, but even the photographs of the one shown by Doctor Abbott, which must have carried some 3,000 eggs, the back of thorax and abdomen were comparatively clear. On the other hand, if the oviposition be light, it is obvious at once that there is a choice of position in placing the eggs upon the crayfish, and that this choice is coincident with the region bathed with the freshest water. The crayfish studied were taken from the Griesa Pond on June 15 and 17, and from the Race Track pool, July 5. The series studied by Doctor Abbott were taken early in July and began to hatch the 8th.

Incubation. No eggs have been observed from oviposition to hatching, but since the eye spots show up about four days before hatching it would indicate that incubation is about the same as with other Corixids.

Hatching. The process appears to be the same as with other Corixid nymphs studied, the egg splitting back in from six to eight lobes.

Behavior of Newly Hatched Nymphs. The nymphs, upon hatching, keep close to the bottom and prefer the dark, according to Doctor Abbott. Their safety depends directly, in these early hours, upon inconspicuousness brought about by their transparency and tendency to remain quiet.

Doctor Abbott's specimens were reared in a large zinc-lined aquarium, having a superficial area of 30 to 35 square feet. His attempts in small jars failed. The writer has carried a generation through in a common glass battery jar without attention, the jar being prepared beforehand. While Doctor Abbott noted that mortality was high from third instar on, many being found dead in the morning, when combined with the observation that the nymphs were more active dull dark days, led him to believe they were more active at night. It might be added that there is a possibility that the activity or tendency to come to the surface at such times may be due to the need for air. On bright days the water plants add quantities of oxygen to the water, and it has been observed that they can be forcibly retained submerged in vessels containing water plants for longer periods than in clear water. In boiled water they become distressed rather quickly.

Number of Instars. There are five nymphal instars which have been described by Doctor Abbott. The description of the egg and nymphal stages is taken from his paper.

DESCRIPTION OF STAGES.

The Egg.

"Length about .9 mm. Breadth about .4 mm. Shape elongate-oval, bilaterally rather than axially symmetrical, *i e.*, one side nearly straight, the opposite strongly curved. Colour grayish yellow (later stages only

were observed); the surface ornamented with a delicate tracery in the form of interlocking hexagons like a honeycomb or the facets of a compound eye. The egg is fastened in a sort of shallow cup which is of a leathery texture and dark brown in colour. The distal end, through which the nymph emerges, is provided with six to eight short lobes arranged in a circle. The appearance of the whole egg is much like that of a minute Grantia sponge.

Dufour described the eggs of *striata* and *hieroglyphica* as acuminate at the free end and placed on a pad. White speaks of the eggs he describes as pyriform and attached at the broader end. He does not mention the pad or cup, nor does Heidemann, of *Corixa mercenaria*. It would be of interest to discover if there is a difference in this regard between different species of Corixids or whether in some cases the pad or cup has merely escaped observation."

It may be added that the ovum has a transparent button and tip, while the body of the egg is yellow.

First Instar.

"Length, about 1.15 mm. Width, about 0.55 mm. General appearance of adult, but wider in proportion to length. Head about three times as wide as long (dorsal aspect); distance from vertex to tip of beak about equal to the width between eyes (ventral aspect). Eyes prominent and conspicuous, deeply pigmented, facets relatively large. The beak is apparently 4-jointed, rather broad and conical. The black tips of the mandibles and maxillæ project slightly between the two halves. The former are somewhat shorter than the latter, curved, with minute serrations at the tips, and may be seen to extend into the head apparently up to the level of the eyes.

"The antennæ are 2-jointed, inserted far down toward the beak, the last joint about one-third the interorbital width in length. Tarsi all 1-jointed. Those of first leg, when at rest, curved over beak as in imago. First tarsi triangular in section, about one-third as long as those of third leg, 3½ times as long as broad, oblong-triangular, broadly rounded above, the comb of bristles prominent. Tibia of second leg three-fifths the length of tarsus and squarish in section with the anterior angles armed each with a row of short bristles. Intermediate tarsus nearly eight times as long as broad, with a ventral row of long bristles and several rows of much shorter ones; tarsal claws weak, variable in length. Third leg sparsely bristled, tarsal joint slightly longer than the tibia or the femur, which are subequal. Body a little less than twice as long as broad, the posterior angles not so truncate as in later instars, provided and armed each with a half dozen rather long bristles. Lateral margin of body with bristles on posterior half only.

"The tracheal system is comparatively simple, consisting of two longitudinal trunks sending off laterals in each abdominal segment, and one stout branch to each leg. Anterior branches supply the brain and the eyes."

Second Instar.

"A marked increase in size is noticeable, the length being now about 1.9 mm., and the width about 0.9, roughly one-half as much. Head strongly convex, the frontal margin with a row of rather long bristles, longest in the middle, shorter toward the eyes. Posterior border deeply sinuate or arcuate.

"Prothorax about as long as mesothorax, the two together a trifle longer than metathorax; the contour of the two together forming a narrow oval. Posterior margin of metathorax straight, anterior margin concave; its median length about equal to that of head. Abdomen truncate, 7-jointed, last joint about one-half as wide as first joint, terminated by two groups of rather long setæ at the angles.

"Tarsi all 1-jointed. First tarsus fringed with moderately long

setæ, about equal to tibia in length. Second legs; tarsus equal to tibia, both together about as long as femur. Third legs with femora, but slightly flattened, tarsus nearly as long as femur and tibia together, clothed with setæ, these longest at the joint, becoming much shorter distally. Colour very transparent. A median grayish line on thorax."

Third Instar.

"Length, 2 mm. Width, 1 mm. Head as before. Eyes a little more than one-fifth the head-width in width. The wing-pads first appear; about three-fifths the length of thorax, sparsely hairy. Thorax one-half as long as wide. Abdomen as before, fringed on the sides by rather long setæ, the posterior angles with conspicuous tufts. Ventral surface sparsely pilose.

"Tarsi all 1-jointed. The whole first leg about equal in length to the femur of second leg. Tarsus about three times as long as broad, terminated by a sharp spine. Second legs slender; tarsal claws as long as tarsus, other joints as in third leg, all feebly setose. Third legs; tarsus 1⅓ times the tibia, the latter equal to femur. Tibia and femur together about equal to femur of second leg. Abdomen strongly truncate."

Fourth Instar.

"Length, 3mm. Width, 1.2 mm. Very much more pigmented and less transparent than previous instars. Posterior margin of head, posterior angles of eyes, and posterior margin of thorax fuscous. Anterior margin of thorax and inner edge of wing-pads with rather dense brownish-black hairs. These together with the pigmented posterior margin of the thorax form a square; a median patch of brown hair joining the band on the anterior margin. General surface of thorax smoky brown with narrow median clear line, and a paler transverse band in the middle. Head pale brown with darker shading on vertex. Whole dorsal surface of thorax and abdomen sparsely hairy, the abdominal segments faintly indicated by transverse brown stripes. A median longitudinal white stripe one-third the body-width in diameter runs the length of the dorsal surface of the abdomen. Within this is a series of large pale brown blotches, one on each segment, the third and fourth of these with a distinct crescent of chestnut brown, marginal third of abdomen smoky, fringed with cilia, but these less conspicuous because of the general hairiness of the body. The wing-pads hardly extend beyond the thorax.

"Tarsi all 1-jointed. First legs as before. Second leg with femur as long as width of head, equal to tibia and tarsus together. Claws one-fifth longer than tarsus. Third leg with tarsus equal to width of head, feathered with dense hairs. Antennæ one-half of the length of tarsus of first leg. Interorbital space two-thirds the width of head, and equal to three-fourths the length from vertex to tip of beak."

Fifth Instar.

"Length, 3.8 mm. Width, 1.4 mm. Dorsal marking as in previous instar, but more intensified. The two median dark brown marks of third and fourth abdominal terga oblong, surrounded by a larger oblong one of smoky brown. Hairy covering of wing-pads and thorax conspicuous, the median patch of the anterior border extending more than one-third the length of thorax down the median axis. Wing-pads extend half way to third abdominal segment. Beak brownish, with short pubescence. Legs pure white, antennæ no larger than before, but fringed with short cilia. Tarsi of first two legs one-jointed; those of third leg two-jointed, otherwise legs as before.

"In comparing the various larval stages one is struck by marked increase in the size of the eyes relative to the size of the head as development proceeds. Another point is of great theoretical interest. As is

well known, there exists throughout the group an extraordinary sexual dimorphism, such that the uninitiated might be led to class males and females of the same species in different families, so great is the dissimilarity in structure. It is of interest to note that the larval stages up to the last instar, with respect to those structures (palæ, frontal fovea, asymmetry of abdominal segments, etc.), that exhibit this dimorphism, are entirely of the female type. The writer has dissected the much larger *Arctocorixa harrisii* Uhl, during the last moults, and has found the same thing to be true. A specimen in the fifth instar just ready to moult may easily be 'shelled out' of its cuticle and, if a male, the irregular arrangement of the abdominal segments will be found fully developed, but entirely concealed by the regular and symmetrical arrangement, characteristic of the females and larvæ."

Summary. Ramphocorixa acuminata Uhl., known in literature and in Van Duzee's checklist and catalogue as *R. balanodis* Abb., winters as adult, places its eggs upon crayfish in such a manner that they receive the maximum amount of fresh water. The species occurs in muddy ponds in the middle west and its eggs are found in June and July. Each instar requires about a week, adults being produced in some seven weeks after the deposition of the eggs.

Palmacorixa buenoi Abbott.

There have appeared life history notes on species of but two of the six genera of the family Corixidæ in this country. The first of these was by Doctor Abbott, and dealt with the only species in the genus *Rhamphocorixa*. The second was a report upon *Arctocorixa alternata* by the writer. This present account considers the biology of a species of the genus Palmacorixa.

There are only two species reported for this genus, *P. gillettii* Abbott, found in Colorado, and *P. buenoi* Abbott, reported for the eastern states. This latter species came to the writer's attention while collecting water bugs at the Field Station, Ithaca, N. Y., on January 19.

The day was very cold and the net stiffened as soon as it came in contact with the air. All still waters were frozen over solidly, but on the south side of the station there was a cement walled ditch containing about two feet of water supplied from a strong spring. Near the spring there was but a thin coating of ice, easily broken.

Amongst the dense tangles of Elodea many active Corixid adults of several species were taken. This was to be expected, for all the water bugs were supposed to pass the winter as adults. However, among this afternoon's catch were many strikingly marked nymphs of some Corixid, all in the same instar. This seemed so unusual that these nymphs were followed in nature and in the laboratory until the entire cycle was established.

So exceptional in its seasonal appearance is this form that no attempt is made to follow the usual order in the discussion.

Collecting throughout the remainder of the winter and early spring established the presence of only the nymphal form of this species. These nymphs were abundant in the pool above mentioned, in the slack waters of Cascadilla creek, known as "Dwyer's" pond, and in the quiet strip of water called "Bool's Backwater," which connects Bool's brook with Fall

creek. Since this Bool's Backwater was surveyed nearly every day from earliest spring to near the end of the season, the field notes taken in that connection afford a splendid outline for the development of this species in nature.

It would appear that this boatman prefers permanent and quiet but fresh waters, perhaps best suited to its needs if some part of the body of water has depth. Along the shores of Beebe lake, only a few hundred yards distant from Bool's Backwater, a large form of this same species was found. The two bodies of water are connected by Fall creek, and the presence of two very distinct sizes seems remarkable. The larger form was never taken in Bool's Backwater, but a very few of the smaller form were taken in Beebe lake, along with the much more abundant large variety. Aside from the decided differences in size, the females are much alike. The males, however, present differences in the arrangement of the palar pegs and in the strigil and abdominal segments. From the material examined, it would seem that the pegs of the smaller form show a greater tendency to crowd out of line, thus forming two lines at one or both ends of the series. The smaller species has a larger, coarser strigil than the other, while the right lateral margin of the abdominal segments are more spinously produced in the larger form. These points are figured on plate XXVII, which see.

Life Cycle in Nature.

Overwintering nymphs were so abundant in Bool's Backwater and other species so rare that it was determined to follow the development of this unusual Corixid in this way. Collecting in early April brought forth only fourth instar forms. April 18, while the waters were still quite cold, the *A. alternata* present were mating and the *P. buenoi* were still in their overwintering stage. There was no change in matters until May 2, when a few in the fifth instar were taken. A count of one catch showed 73 per cent still in the fourth instar. It was on this date I noticed the May fly nymphs, which I have called the "scooter." This nymph is mottled, with about the same shades as a Corixid nymph, and is fully as inconspicuous. They occupy the same foraging grounds, and it is the protective resemblance and agility in both that insure their perpetuity in the world. On May 9 adults of *A. alternata* and the overwintering nymphs were notably "mited." A collection of the *A. alternata* showed 85 per cent of them to carry the water mites. By May 19 most of the nymphs were in the fifth instar. May 21, 97 per cent of the catch were in fifth instar. In a count of 300 nymphs, only one per cent of them were infested with mites, and in this case only one mite on each. Those infested with mites were delayed in molting. June 4 was a fine, warm day, following two or three before it, and the first adults of the *P. buenoi* were taken. There were 95 per cent still in the fifth instar. The first instar nymphs of *A. alternata* were taken on this date, which indicates the ease with which the overwintering species could be followed up to this time. Most of the adults of *P. buenoi* were new fledged, as indicated by the softness of their integument. In fact, some were creamy yellow, showing that transformation had just taken place. Another item of

interest in regard to these early adults is that out of a catch of 29 specimens 22 of them were males. If percentage for so small numbers is worth anything it indicates that 79 per cent of those taken at this early emergence were males.

In a collection made on June 8 were found 33 specimens—12 fifth instar nymphs, seven females, and thirteen males. It is worth noting that the mites that had been clinging to the fifth instar nymphs were molting to the free state at this time, just ahead of the time for these nymphs to become adult. June 13 found most of the individuals adult. One nymph in perhaps 200 adults.

Eggs began to appear about June 20, which was a week later than noted in the laboratory. Most of the eggs had hatched July 11, and in a catch made July 13 there were:

4 first instar *P. buenoi.*
78 second instar *P. buenoi.*
83 third instar *P. buenoi.*
18 fourth instar *Arctocorixa alternata.*
10 fifth instar *Arctocorixa alternata.*

From this it is seen that to this date the two species have remained separate. These counts were made after the reared material had been studied and both species could be recognized readily. What happened in this pool after this date can not be determined, for no collections were made later than July 19.

Life Cycle in the Laboratory.

The development of this species in the various aquaria followed quite closely the changes taking place in nature, being, however, somewhat earlier.

On April 20, a considerable number of nymphs were brought in from Bool's and placed in a large rectangular aquarium prepared for them. On April 28 two had molted to the next instar, and by May 15 they were all in the fifth instar and doing fine. Up to June 2 this aquarium was kept at a north window in an upstairs room, where no sunlight reached it. Since no adults appeared here, while they were doing so elsewhere, this was moved to a sunnier place outside, with the result that by June 4 many had tried to emerge, numbers dying in the attempt. Under laboratory conditions, molting appears to be a precarious process.

The first adults to appear during the spring from overwintering nymphs were a male and a female, which died emerging May 11. By May 15 several had made the transition successfully, and it was possible to determine the species presenting this peculiar wintering habit. It will be noted by field notes above that there were no adults in Bool's on May 21, so that those in the greenhouse were brought to maturity earlier than in nature.

In another aquarium adults began to appear June 5, and were followed the next day by the majority of the others. The first eggs were noted June 13, and were numerous on the sides of the jar June 14, thus establishing a maturation period of about eight days. A similar time is required for incubation.

In one large aquarium jar was placed ground cattail stems to the depth of one-half inch. The cattail had been soaking all winter in the pool and was readily reduced to a flocculent mass by passing it through a grinder. After drawing off the water two or three times, and replacing with fresh water, the jar was ready for use.

Bugs of this species were placed herein and maintained themselves throughout the season without further attention. The overwintering nymphs became adult, mated, and laid their eggs, which hatched in due time. On July 6 all of the adults were dead and nymphs up to the second instar were noted feeding. The hot rays of the sun shining through the glass wall of the jar were not favorable to the bugs, though some survived, for by August 7 there were several nymphs in the fourth or fifth instars. August 21 three adults had arrived and the remaining nymphs were in fifth instar. These became adult sometime during the first week in September. The rearings were not followed closely from this time on, but the evidence on hand seems to show that these adults that emerge the last of August give rise to the nymphs that overwinter. Thus there are two generations a year, one overwintering as a nymph and becoming adult in June, the other coming on in July and emerging in late August. Some fifty pairs of new fledged adults of the first generation were placed in petrie dishes in an attempt to ascertain the number of eggs each female would lay. In every case the bugs died without laying a complete egg complement. Floating cages were placed in Beebe Lake in a like effort, but were disturbed, and after two or three attempts the project was abandoned. From the immense numbers of these bugs present in suitable waters, there is every indication that they are prolific and capable of foraging in close quaters. Since both nymphs and adults have been recovered from fish stomachs, they afford a possible source for the increase of a food supply by their artificial propagation. Of all the Corixids with which the writer is familiar this species presents some of the most likely possibilities in the regions where they may be found.

The absence of functional wings in the majority of them and ability to forage in close quarters are factors quite in favor of their use in pools set apart for their artificial propagation.

DESCRIPTION OF STAGES.

The Egg.

Size. Height, 0.546 to 0.572 mm.; diameter, 0.325 to 0.39 mm. The egg when first laid inclines to the minimum measurement, and when containing well-developed embryo attains the greater dimensions.

Shape. Varies with development within, asymmetrically ovoid. Anterior end more slender and terminating in the usual micropylar tip. Greatest diameter about the middle of the egg. The shape of the freshly laid egg is more slender than that of the one ready to hatch.

Color. Pearly white when first laid, darkening to yellow as embryo develops within. When ready to hatch the color is yellow, the base of the micropylar peg is black, and the claws of middle legs of the nymph within are visible as dark lines. The eyes are red, and the dorsal abdominal glands show through as faint pink blotches.

The attachment disc of the egg is smaller than in some of the other species. Two eggs are figured on pl. XXVIII, fig. 15. These are drawn to same scale and show the difference in size and shape between the newly laid egg and the older egg.

First Instar.

Size. Length, 1.09 mm.; width of body, 0.65 mm.; width of head. 0.494 mm.; space between eyes, 0.299 mm.

Shape. Flat, width of body greater than one-half the length. As time for first molt approaches the body becomes thicker in dorso-ventral line, a fact which holds for the other stages as well.

Color. Eyes dark red, body mottled with smoky grayish-black. Pattern distinct, as shown in pl. XXVII, fig. 7. Pattern about as described for second instar, with the exception of mesothorax, where irregular blotches of dark pigment replace the transverse arcuate bands described below.

Structural Peculiarities. The limbs in this stage are proportionately larger than in following instars. The stout hairs fringing the limbs are not as definitely arranged for a given purpose as later. The fringe of swimming hairs on hind limbs made up of few hairs. The middle limbs, which in the adult are so slender and long, are thick and no longer than the hind limbs. The femur is as long as tibia and tarsus together, which are subequal. Tarsus is 1-segmented, and ends in two long slender claws, which nearly equal the length of tibia and tarsus together.

Hind limbs not conspicuously flattened as in later forms, the swimming hairs few, perhaps a dozen in each row, and confined to the tarsal segment, which ends in a pair of almost spine-like claws. These claws are about half the length of tarsus, and straight, save for a slight deviation from a straight line at a point two-thirds the distance from their base.

The dorso-caudal side of hind tibia with an irregular row of 10 to 12 short, stout spines. A few other less conspicuous spines upon this segment and two longer ones on caudal margin of distal end of this segment.

Middle Leg. Two short spines on anterior margin of femur, and two long ones near distal end. Tibia sparsely covered with short, stout hairs, a long one on anterior margin near base, two near distal end. The marginal series of spines as delineated.

Caudal Segment. Pair of short peg-like spines astride the median line. Caudo-lateral angle of body with five pairs of long spines, cephalad of which are two short ones. The penult segmental margin, 12 long spines cephalad of which are two or three short ones. The antepenult segmental margin, a pair of subequal long spines and cephalad of these two or three shorter ones.

Second Instar.

Size. Length, 1.638 mm.; width of body, 0.858 mm.; width of head, 0.65 mm.; distance between eyes, 0.364 mm.

Shape. A little more elongate than in first instar, the width now about half the body width.

Color. Eyes very dark red, as are the dorsal abdominal glands. Cephalic aspect of head shows the cephalic end of the median dark longitudinal band, noted below. This band extends down upon the front to the level of the lower inner angles of the eyes. A dark spot lies laterad of the lower end of the median band, about three-fifths to two-thirds the distance to the inner angle of the eye. Dorsal aspect: head with median longitudinal smoky band visible from front to highest point of vertex. Between the caudal end of this line and the eyes lie two pairs of dark, more or less elongate, spots. The prothorax is marked on each side with two dark, roughly triangular spots of unequal size, their apices directed toward the margins. The smaller spots just laterad of median line and the larger ones laterad of these. The prothorax often marked by a transverse band on caudal margin. The mesothorax is marked by three pairs of very irregular and often indefinite, smoky blotches of unequal size. The abdomen is marked by reddish transverse bands that follow the abdominal sutures. These give way to triangular sooty blotches at the margins. The two large, dark dorsal glands have arcuate anterior margins and convex posterior margins. A dark circular spot marks the anal opening. The middle limbs have the joint between femur and tibia slightly smoky, and the tarsus is crossed by faint median band. The tibio-tarsal joint of hind leg is dark and a band crosses the middle of the tarsus. A dark spot on the hind tarsus is characteristic of all the nymphs of this species, and mark them from the nymphs of *Arctocorixa alternata* taken at the same time.

Structural Peculiarities. The hairs on limbs in more definite series. Swimming fringe of hind legs still confined to margins of tarsus for the most part, but composed of a larger series of more closely set hairs, some 40 in number. The claws of the hind tarsus are now one-third the length of this segment, and appear incised about midway of their length. The relative lengths of limb segments much as in the previous instar, but the entire limb more slender. The marginal series of spines as delineated in the figure. The pair of peg-like spines astride the median line on caudal margin in this and all other instars. A cluster of five long spines at caudo-lateral angle of last segment and about five short ones anteriorly. The penult segment of abdomen is margined by five spines, the second one from the caudal margin elongate. The antepenult segment of abdomen is margined by about seven spines, the first, second and fourth longer than the others, the second one being twice as long as any of the rest

Third Instar.

Size. Length, 2.21 mm.; width of body, 1.04 mm.; width of head, 0.806 mm.; distance between eyes, 0.286 mm.

Shape. Length now two and a fifth times the width.

Color The face has the dark blotches between the lower inner angle of eye and the dark longitudinal median line of former instars. In dorsal view the head is marked either side of the longitudinal median

stripe by a spot of dark pigment. On the hind margin of the head there are two spots, visible only when the head is bent forward. The caudal margin of prothorax is margined with a dark band. Base of mesothoracic wing-pads marked with dark irregular spot. Hind margin with arcuate band of color and two faint arcuate bands upon the disc. The metathorax is marked with pairs of irregular smoky spots as delineated. Abdomen markings as in former instars.

Structural Peculiarities. The wing-pads are now well marked and extend back slightly more than half the length of the margin of the meso- and metathorax taken together. Tibia as well as tarsus of hind leg with swimming fringes. Claws of hind tarsus now not more than one-fifth the length of the tarsus. The claws present the peculiar incised appearances as before. The middle femur is longer than the tarsus and tibia together. The marginal series of spines as delineated.

Fourth Instar.

Size. Length, 3.072 mm.; width of body, 1.43 mm.; width of head, 1.19 mm.; distance between eyes, 0.39 mm.

Shape. About as in third instar.

Color. The ground color is pale fuscous with darker markings ranging from smoky to reddish-brown. The face bears the pair of smoky rectangular blotches noted in former instars. From above the vertex is marked by three longitudinal stripes. The median one is slender and the lateral ones irregular in outline. The thorax is marked as delineated in the plate. The darker part reddish-brown, the scroll on the metathorax being the most characteristic. The abdomen is crossed by reddish-brown transverse bands, which at the margin of abdomen blend into triangular smoky spots. The body of abdomen is further marked by two longitudinal broken bands of fairly dark pigment, one either side of the dorsal glands. These converge from the base of the abdomen to the caudal end, where they meet. The caudal margin of hind tarsus bears a roughly triangular dark blotch, its apex reaching in some cases two-thirds of the distance to the cephalic margin.

Structural Peculiarities. The wing-pads now extend more than two-thirds the length of the meso- and metathorax. The hind limbs are now well adapted for swimming, the hind tarsus being broad and flat, and the swimming fringe very complete. The claws are reduced now to perhaps one-seventh of the length of the tarsus, and are less conspicuous than formerly. There is a small tibial comb of six short spines at distal end of the tibia. This structure is present but inconspicuous in the previous instar. The marginal series of spines as delineated.

Fifth Instar.

Size. Length, 3.9 mm.; width of body, 1.7 mm.; width of head, 1.3 mm.; distance between eyes, 0.39 mm.

Shape. As before, save that the length is greater in proportion to width.

Color. Color pattern substantially as in previous instar. The long wing-pads, however, are darker.

Structural Peculiarities. Wing-pads now long, reaching to the second abdominal segment. The hind tarsus is still 1-segmented, and claws reduced. The tibial comb of hind tarsus is composed of longer spines than before. The neutrality of the caudal segments of the nymph, in contrast to those of the adults, is illustrated in the drawings on plate XXVII. A study of specimens killed while emerging shows the marked transformation that takes place between nymph and adult. The antennæ of nymph are heavy blunt-tipped appendages, plainly 2-segmented, with a constriction on the distal segment that may indicate that it is divided into two segments. See drawing on plate XXVII.

Behavior of Adults There are some points in the economy of the lives of these insects worth noting. It is one of the very few water insects overwintering as a nymph. In fact, the only one known to the writer. For some time it was not clear as to why there should be this exception. It seems, however, that since the species seldom, if ever, flies, but lives in permanent waters, there is no occasion for the annual fall and spring migrations indulged in by other species. Most Corixids fly to larger pools to winter and in spring fly back to repopulate the shallower ones.

The adults of this species are given to burying themselves in the flocculent ooze on the bottom of the pool, and are thus difficult to locate. In common with other species, they come to the surface for air, and if in water of any depth are likely to head downward from the surface, swimming in a spiral to the bottom.

In accounts dealing with the stridulation of the male Corixids it is stated they make their music at night. Some of these which were brought into the laboratory surprised us with their chirping one cloudy afternoon. Their stridulation was distinctly audible across the room and sounded somewhat like that of distant crickets, save that the chirps came forth in couplets.

Summary. The species here discussed winters as a fourth instar nymph, reaches the adult stage about the first of June, and after a maturation of eight days begins oviposition. This generation becomes adult during August and starts the generation that overwinters as nymphs.

The species is capable of living in great numbers in a pool. The nymphs have been seen to strip the chlorophyll from filaments of Spirogyra and an examination of the stomachs of many of them shows that they consume quantities of living chlorophyll from the lower plant organisms that make up the flora of the pool bed. This herbivorous tendency reduces the uncertainty of food getting and accounts in a measure for their success. It has further been demonstrated that they can complete their life cycle by foraging upon a flocculent mass of ground Typha and its attendant population.

The facts above presented, when combined with the lack of functional wings, suggests the practicability of rearing them artificially. Since the nymphs of this species have been recovered from the stomachs of fishes, it may be that this form, easy to manipulate, can be utilized in increasing the food supply for young fish.

Arctocorixa alternata Say.

These are medium-sized Corixids, barred with light and dark brown, that are to be found in pools, ponds and quiet stretches of streams throughout the country. They present a perplexing range of variation in size and pattern and afford a most difficult problem in the fixation of the species. The writer published an account of the life-history of the form common in Kansas, and presents here some notes on the variety prevalent in the waters about Ithaca, N. Y.*

Habitat. While this bug has a wide range of habitat, it is found perhaps more than any other in streams. About Ithaca it was often taken in Bool's Brook, while other species, taken in the upper spring-fed pool and in the fresh water at its outlet, were absent from the stream proper.

Hibernation. In common with many other Corixids this species is active in open water throughout the winter, the adults exhibiting considerable activity even in waters covered by a layer of ice.

Mating. The first mating noted in nature took place April 17, in a pool by a railroad trestle. The water of this pool was still very cold. Pairing takes place in the water, and lasts for various lengths of time, often an hour or more, during which time the female continues to feed. The male mounts the female and clasps her with his forelegs while the tip of the abdomen is passed around the left side. The pegs on the male palæ make the embrace more secure, while the peculiar structure called the strigil, upon the right side of the abdomen, without doubt serves a similar purpose. This latter was considered by Handlisch as an instrument for stridulation, but this is denied by other workers.

Although mating may take place any time during the day, it has most frequently been observed toward evening.

Oviposition. The first eggs were taken April 19. There were 59 of them laid upon the sides of the aquarium during the night by five females. This is a little earlier than they were found in nature. In nature the eggs are attached singly to any available support in the water. They have been found on the stems and leaves of various water plants, upon sticks and boards, upon the stones, and even on the shells of living snails.

Incubation. The duration of incubation of the eggs depends somewhat upon the temperature of the water. Those laid earliest in the spring began hatching May 2, after a period of two weeks. In warmer weather the time may be reduced by half.

Hatching. The process of hatching with the Corixids is different from that observed in the case of other water bugs. The egg shell breaks about the base of the micropylar peg and then splits into six or seven sections, each one of which curls outward and downward as the opening is enlarged. The writer has often had the eggs under observation at time of hatching. First the top of the egg bulges slightly, then there is a sudden giving away and the nipple-like tip of the egg pops loose

* Although this was identified for me as the same as the Kansas form, I am satisfied from careful study that the varieties are distinct species.

at its base and the loose ends peel back, one of them bearing the attached micropyle. The process is now best viewed from the side. First a clear bubble appears, bound by a delicate transparent membrane. This grows until it reaches a height about one-fifth that of the egg, and stops. Then gradually the head of the nymph comes up and fills the bubble. (See pl. XXVIII, fig. 12.) The process so far may have consumed some three or more minutes, but the nymph is not yet free. Another heave, the membrane that enclosed the bubble splits and a moment later the nymph, plastic and soft like a worm, swells the exposed part of the body repeatedly until it is all but free. Then it may lie exhausted a few moments, or even minutes, before a final kick sets it at liberty. As soon as it is liberated it is capable of swimming rapidly for several centimeters, and then appears exhausted. It begins feeding before the color pattern is complete.

The hatching process takes place under the water, and the behavior of the new-fledged nymph in relation to an air supply is noted below. The time required for emergence from the egg ranges from four or five minutes to a half hour. One egg began hatching at 3.51 p.m. The parts of the shell peeled back in six divisions. Midway between the eyes at the apex of the hatching nymph there was an organ that pulsated vigorously at times. At 4:15 the upper edges of the red eyes began to show and the part before the eyes was larger than the remainder of the head. One-half of the eyes was exposed at 4:25. Body completely out at 4:31. The limbs of the nymph, incased in the shell, are stretched caudad upon the venter, and the margins of the body are rolled ventrad. The ventral side of the nymph is on the bulging side of the egg, and there is a deep transverse fold on the dorsum, so that the back of the head and dorsal abdominal glands are approximate. Figures of the hatching nymph are shown on pl. XXVIII, fig. 12. The remains of this thin embryonic sheath lie about the opening of the abandoned egg like a cast-off garment. (See fig. 12.)

Behavior of Newly Hatched Nymphs. The nymph just freed from the egg shell presents little pigmentation. The limbs and the flat margin of the entire body are as transparent as glass. The head and central part of the body is pale yellow. The eyes are red and the two dorsal abdominal glands are a pale red. There are two faintly pale pink indefinite regions laterad of the middle line on the thorax.

This transparency makes it possible to study the question of respiration, for as soon as the tracheæ fill with air they become silvery. There is still a large problem to solve relative to the reception of the first air supply. Tillyard's work with the dragon-fly nymphs suggests an interesting field of study with Corixid nymphs. A few observations were attempted in a preliminary way. Eggs ready to hatch were placed in a slide cell, the chamber filled with water and covered over with a glass cover slip. The only air then available to the nymph would be such as is found dissolved in water. By the time the nymph was a half hour old, however, there usually collected a bubble of gas somewhere under the slip. In those nymphs observed the tracheæ remained undefined until the little bug made contact with one of these bubbles, whereupon they im-

mediately became silvery. From the behavior of young Corixids, it would seem that respiration must take place through the skin for they seldom come to the surface, yet in the few experiments tried it was not demonstrated that air was taken up in that manner. The nymphs were able to survive for many hours in cloth covered jelly glasses submerged in water.

Number of instars. There are five nymphal instars, which are shown on plate XXVI.

Maturity. This could not be determined from the overwintering adults and was overlooked in the summer. The laboratory notes were obtained from a start of nine individuals that were placed in a large circular aquarium April 3. Seven of these were females. By the last of the month there were but three individuals remaining, and May 9 only two were left, but first instar nymphs had appeared. Some of these changed to second instar nymphs May 12, and reached the fourth instar June 2. The two overwintering adults were still alive and laying eggs. June 10 found all stages from first instar to the fifth present. June 14 the first one of the spring generation reached the adult stage, followed by another on the 19th. There were still first instar forms present. In fact, eggs and newly hatched were present up to July 18. Since the overwintering adults were not removed, it is impossible to say whether the young represent a second generation or merely a continuation of the first. The hot weather of the last week in July brought the rearing to a close, and was valuable only in giving all the nymphal instars for study and establishing the approximate time for the emergence of the spring brood. It is certain that the adults of one year may live to see adults of the next.

Parasitism. In Bool's Backwater, where this Corixid was found throughout the spring in company with the nymphs of *Palmacorixa buenoi*, the infestation of Hydrachnids was heavy. On May 9 a large catch of this species showed 85 per cent of the bugs infested with one or more mites, some of them with a dozen. May 15 there was not an adult to be found that did not bear mites. On June 8 the mites freed themselves from their hosts in the laboratory, and on examination of the insects in the pond June 11 found the boatmen much less burdened than before and almost entirely free June 13. June 18 not a single "mited" Corixid was noted.

DESCRIPTION OF STAGES.

The following brief description of size and color is given for comparison with *P. buenoi* of same pond. The structural comparative studies of nymphs of various species are reserved for a future paper.

The Egg.

Size. Diameter, 0.369 mm.; height, 0.372 mm.

Shape. Variable, depending on development of embryo within. In general ovoid, but with the usual greater convexity of one side.

Color. Pearly white when first laid, darkening to yellow. There is a hexagonal reticulation plain to see under high power and proper lighting.

First Instar.

Size. Length, 1.29 mm.; width of body, 0.754 mm.; width of head, 0.598 mm.; distance between eyes, 0.416 mm.

Shape. Width greater than one-half the length. Body very flat in the newly hatched.

Color. Newly hatched almost transparent, but in the course of a few hours assuming the color pattern delineated in fig. 8 of pl. XXVI. General color is pale yellow, the darker pigment being smoky. The prothorax, mesothorax and metathorax each bear a pair of irregular smoky blotches. The pair on the metathorax being large and extending to lateral margins of the segment. Part of the color of the abdomen is due to the food in the digestive tract within. In the nymphs about ready to transform the entire body is darker.

Second Instar.

Size. Length of body, 1.77 mm.; width of body, 0,936 mm.; width of head, 0.78 mm.; distance between eyes, 0.442 mm.

Color. Darker than in other instar. The body transversely banded with darker pigment. The transverse lines on thorax and abdomen are reddish-brown. The other dark areas smoky. A smoky band parallel with margin distinguishes this species from the same stage of *Palmacorixa buenoi.* The head is marked by three longitudinal smoky bands.

Third Instar.

Size. Length, 2.31 mm.; width of body, 1.19 mm.; width of head, 0.99 mm.; distance between eyes, 0.52 mm.

Color. Third instar nymphs often darker than second and have a definite color pattern. The hair upon the wing-pads now appears, and enmesh the air. Head: eyes dark red, head pale, marked by a median longitudinal dark band; faint lines lie between this and the eye, one on either side. Rear margin of head fringed with black hairs especially near the dorsal median line. Margin of wing-pads dark and fringed with a pile of fine dark hair. Prothorax hidden. Mesothorax is traversed by a reddish-brown band near posterior margin. The hairy fringe of fore wing-pads continues across the dorsum. Metathorax pale with a smoky pattern of five spots, the median one crossed by the pale median streak that reaches the length of the thorax. These spots consist of crescentic patches in front, their inner horns almost touching the median triangular patch of color, on either side of which lie the right angled patches. Posterior margin reddish-brown. Abdomen: margin smoky gray, the suture between the tergites marked by dark reddish-brown bands; two rows of irregular quadrangular patches of smoky color lie on either side of median line, from third to sixth, inclusive. Three pairs of odoriferous pores, front ones on caudal margin of third segment small, the second and third pairs larger, and the very dark glands are apparent beneath the integument. Dark ring around anus. Legs for the most part pale; hair fringe dark.

Fourth Instar.

Size. Length of body, 2.86 mm.; width of body, 1.38 mm.; width of head, 1.2 mm.; distance between eyes, 0.494 mm.

Color. Pattern distinct. Head with median dark longitudinal band. Wing-pads dark, covered with dark pile. Caudal margin of mesothorax smoky. Metathorax with an arcuate band of reddish-brown interrupted on the median line. Two other pairs of smoky spots are upon the disc of the metathorax. A pair of small triangular spots separated by a narrow median line of pale and a larger pair of indefinite quadrangular smoky blotches laterad of these. The intersegmental lines of abdomen reddish-brown, very distinct. The large dark abdominal scent glands open by paired pores on caudal margin of the fourth and fifth segments. The abdomen is marked by a smoky submarginal band and each segment bears two pairs of rectangular smoky gray spots, the outer ones forming distinct longitudinal rows.

Structural Peculiarities. Wing-pads reach to the posterior margin of the metathorax, as in other Corixids.

Fifth Instar.

Size. Length of body, 4.21 mm.; width of body, 1.61 mm.; width of head, 1.46 mm.; distance between eyes, 0.624 mm.

Color. Pattern as in fourth instar, only more striking and darker. The two pairs of spots on disc of metathorax united to form a transverse arcuate band. Posterior margin of metathorax with broad reddish-brown band.

Structural Peculiarities. Antennæ 2-segmented. Wing-pads extended past the posterior margin of thorax, as in other Corixids of the same instar.

Summary. Arctocorixa alternata has the widest range of waters of any of the boatmen studied. It has been the only one commonly taken in flowing streams. The species winters as an adult and begins mating in the region of Ithaca, N. Y., about the middle of April, while the waters are still very cold. Copulation takes place under water and lasts sometimes for hours. Oviposition begins shortly and continues until some of the young become adult, if not longer than this. The eggs hatch in from one to two weeks, depending on the temperature, and the instars require about one week for each stage. The last stage occupying a few days longer. The first generation emerges about the middle of June.

Food of Corixids.

INTRODUCTION.

In a paper which appeared in the Journal of the New York Entomological Society, 1917, the writer called attention to the fact that the water boatmen gather their food supply from the ooze at the bottom of the pool. This flocculent material they sweep into their mouths by means of the flat rakes of their fore legs. In view of the discrepancy that exists between textbooks and the writer's notes on the subject, he deems it worth while to present under this chapter heading some of his data relating to the question, even at the expense of the general balance of the work. Therefore, material that would otherwise be presented in a single paragraph is given a larger treatment under the following outline:

OUTLINE OF STUDY ON FOOD OF CORIXIDS.

- Historical sketch.
- General habits of Corixids.
- Structural adaptations.
    - External.
    - Internal.
- Studies relating to the food of Corixids.
    - Object.
    - General plan of experiments.
        - Pure cultures and surveyed cultures to determine essential forage and selected forage.
        - History of cultures.
        - Survey of culture.
        - Analysis of stomach contents.
        - Technique.
    - Special studies. (Selected as typical.)

HISTORICAL SKETCH.

De Geer, 1778, says that Corixids are carnivorous, and Latreille, 1802, says, also, "Leurs habitudes sont carnassieres." Since that time all textbooks and treatises relating to the general habits of water bugs either state that they are predatory or are silent regarding their feeding habits. In a careful review of the literature the writer has been unable to find a suggestion on the part of any one to the effect that the

water boatmen have any herbivorous habits. He believes, however, that the posthumous paper of H. Rathke, 1861, sent in by his pupil H. Hagen, and dealing with notes on *Hydrometra lacustris* and *Naucoris cimicoides,* treats really of a Corixid and not an Naucorid. In spite of the fact that Kirkaldy, who must have had a good knowledge of German, for he wrote one large paper in that language, quotes from these "Studien Zur Entwicklungsgeschichte der Insekten" in his account of the life history of a Naucorid, the writer cannot accept the account as dealing with a Naucorid at all. The description of the eggs certainly applies to Corixid eggs, not to any Naucorid eggs the writer has ever seen described. Let the reader examine the drawings of the eggs of the Corixids on plate XXV, and then read carefully the following:

"Eier eines Insektes (*Naucoris cimicoides*). Es waren dieselben einzeln, doch mit unter in ziemlich grosser Zahl in der Nähe von einander an die untere Seite der Blätter von *Polygonum amphibium* angeheftet. Sie hatten eine Lange von ½''' und beinahe die Form einer Citrone nur waren sie ein klein wenig länger und gingen an dem einenende in einen sekr kurzen, aber auch sehr dicken Stiel über, auf dem sie angehftet waren, so dass sie mit der achse auf dem Blatte senkrecht standen Die Eischale war bedeutend dick, entweder rein weiss oder weiss mit einer Beimschlung von Lehmforbe, fast ganz undurchsichtig, starr und hart, so dass ich in ihr Kalk vermuthete. . . ."

The eggs were lemon shaped. They were perpendicular to the support. The description fits the egg of some Corixids, but not of Naucorids. The notes go on to state that the eyes turned carmine red, that the head of the embryo lies always on the free end and comes out first, etc. Having concluded that Rathke must have been watching a young Corixid, the following note is indeed of interest here:

"Die Jungen schwammen sehr schnell, waren uberhaupt sehr beweglich und frassen, obgleich sie einen kurzen Rüssel hatten, zerbrockelte und zergangene *Conferven* und Pristleysche Materian, wodurch ihr ganzer Dormkanal unrein grüne Farbung erhielt."

The larvæ ate the Conferva until the intestine was green! Now it may be that Nancorids do the same, though the writer is taking the liberty to transfer this note to the place where he thinks it belongs, and to credit to this scientist the first and only note on the herbivorous tendency of a water bug. As before stated, all the others have classed Corixids as carnivorous. Thomas, 1871, gives the account of *Corixa ovivara* West.,

which lives in the rivers of Canara and which he says eats fish eggs, from which fact Westwood derived its name. The observation follows:

"I observed it myself in a still hollow in a rock, where the water was quite clear and only two or three inches deep. The insects kept tossing the ova up from the bottom and following them closely up to the surface whence they gradually subsided to the bottom of their own weight, the insects apparently adhering to eggs all the time, but the moment they were at the bottom they vigorously were tossed up again. I daresay it attacks other spawn also, but the ova I saw it engaged with were those of the Masheer barbas mosal, commonly called 'Masheer,' the most valuable fish in the Indian rivers."

Mr. Thomas sent an extract from the report of Pisciculture in S. Canara "detailing experiments made by an intelligent observer to test the destructive habits of this insect. In one instance a hollow was watched in which were many freshly deposited ova but no Corixæ. The next morning the latter were there in large numbers, and nothing left but the empty egg shells. In another experiment the ova were placed in a finely woven basket and the Corixæ immediately came in quantities and endeavored to penetrate from the outside."

White, 1873, made careful studies of the behavior of Corixids, and described their feeding movements but stated,

"I have not been able to make out satisfactorily of what the food of these insects consists. (Westwood has recently described an Indian species which is said to feed on eggs of fish.) Evidently White doubts the occurrence of the observation. They often rest on a stone and seem to scrape its surface with the palæ which they bring rapidly and alternately to the mouth. In the same manner they scrape a root of Lemnæ passing it rapidly between the palæ. On examining a stone from which a Corixa had apparently been obtaining food, a small alga and a few Rotifera and other animalcules were seen."

Kirkaldy, 1905, came, through his observations of their behavior, to state, "Dufour says they are carnasial. I think that small worms, Rotifera, etc., form a large part of their food. Kulgatz, 1911, in "Die aqatilen Rhynchoten Westpreussens" describes the front legs of Corixa as "Organe zum Packen und Frestholten der auszusaugenden Beute" and Brocher, 1913, says fore legs are for prehension "Si un petit animal, larve ou elles l'attrapent et le maintiennent applique contre leur bouche . . ."

The writer has given at some length the observations of others. He has observed Corixids catch prey, but finds that

the observations do not represent the usual feeding behavior, which is given elsewhere.

GENERAL HABITS OF CORIXIDS.

Buchanan White, 1873, gives us perhaps the best general account of the behavior of the Corixids. Johannes Hagemann, 1910, published an extended dissertation on the anatomy and behavior of these insects.

White pictures them so well that his words are here repeated:

"The adult Corixa in swimming uses only the posterior legs. These legs are also used for cleaning the elytra. In doing this the animal uses one or both legs, brushing the pronotum, elytra, the underside of the hind body, and the long hairs at its end. To assist perhaps in this cleaning process, the inside of the hind tibia and the base of the first joint of the hind tarsus are provided with what may be called the comb or rake hairs. These are shorter and stiffer than the swimming hairs, and are widened and flattened at the extremity, being in fact somewhat oar-shaped, and truncate at the apex, which has five long teeth. These teeth are admirably adapted to rake out any particles of foreign matter which may have lodged in the fine rostrations with which the pronotum and elytra of many species are sculptured. The species which have no rostrations (such as Macrocorixa) are, equally with the rostrate species, provided with rake hairs. These rake hairs are not present in the young. The middle legs are used for standing on, the long claws clasping stones or plants, and the body of the animal remaining at some distance from the object rested on. The animal can also walk in a kind of way with these legs, its progress being at the same time assisted by short, jerking strokes of the hind legs through the water. When at rest and not clasping anything with the claws, the animal rises to the surface of the water. The front legs or palæ are used for feeding. When in action they are brought rapidly and alternately to the rostrum. In action they hang downward, their tips approaching each other; in swimming they lie backward along the sternum."

A glance at the photograph of the living bugs under water shown on plate III will indicate their characteristic poise. The boatmen spend most of their time in the shallow waters, where they rest upon the bottom, their mottlings of yellow and brown rendering them inconspicuous midst the flocculent bottom ooze. It might here be mentioned that the May fly nymph, living in the same situation, is similarly camouflaged. Now and then the boatmen swim quickly to the surface, expose the thorax for a brief moment, and dart below again. In turbid waters the presence of the boatmen is determined only by the brief flashing of their bodies as they take air at the surface.

STRUCTURAL ADAPTATIONS TO FEEDING.

External.

The Corixids possess the most obvious adaptations of their limbs to definite functions of any of the water bugs. As early as 1833 Leon Dufour, in his "Recherches anatomiques et Physiologiques sur Les Hemipteres accompagnees de considerations relatives a l'histoire naturelle et a la classification de ces insectes," gave a detailed description of the various limbs of Corixids. In 1873 Buchanan White, to whom we owe a great deal for a splendid series of notes regarding Corixids, mentioned the function of the different parts, based upon his personl observation. He states that the hind limbs are flattened and fringed for swimming, that the long, slender middle limbs anchor the bug to some submerged object, and the fore limbs are employed in food getting, though he confessed his uncertainty as to the forage gathered.

Comstock, in his "Introduction to the Study of Entomology," also notes the differentiation of the limbs.

The very unique mouth parts that led Borner, 1904, to place them in a suborder by themselves, and for which he proposed the name *Sandaliorrhyncha,* are well adapted to the unusual method of feeding practiced by these insects. There is no extended beak as in other bugs, yet a morphological study of the various parts, such as those made by Metschniikoff, 1866, Giese, 1883, Wedde, 1885, Heymons, 1899, Bugnion and Popoff, Muir and Kershaw, and others indicate the close relationship of these with other bugs. The drawings on plate XXX show the mouth parts. The face of the bug is seen to be flat with the buccal opening on the front side rather than at the tip. Two triangular flaps, controlled by muscles, permit the enlargement of the orifice. The stylets are very short and stout, the outer pair blunt-tipped and notched on their outer margins. A condition quite different from the pointed and retrorsely-barbed stylets of Notonecta, for instance. The inner pair are broad, placed one above the other, and rolled into semi-cylinders. Bugnion and Popoff say of these internal stylets of Hemiptera: ". . . The internal stylets forming by their juxtaposition two conduits, very fine, one of which ordinarily placed on the dorsal side is the "Canal de succion" which is continuous from beak to

pharnyx, while the other, situated on the ventral side, is the "canal of execution" (outlet of salivary glands.)

With the Corixids the intake canal is relatively large, allowing the ingress of large solid particles.

Internal.

The œsophagus, as shown on plate XXX, is slender as in other Hemiptera, but the mid-gut is large, accommodating a considerable quantity of food. The length is not strikingly greater than that of other bugs, such as Notonecta. The slender œsophagus enlarges to form the œsophageal valve, and the tract greatly enlarges to form a series of pouches. It then narrows slightly to form a more even cylinder. At about the level of the fifth abdominal segment it turns to the right and folds forward to near the front margin of third abdominal segment, where it makes a dorsal turn and bends caudad in nearly a straight line to the anus. The mid-gut terminates shortly before the last bend, as indicated by the attachment at this point of the four Malpighian tubules. An elastic walled rectal pouch is present, on the dorsal wall of which terminates the Malpighian tubules.

STUDIES RELATING TO THE FOOD OF CORIXIDS.

Object and General Plan.

Having determined the source of the food supply of the boatmen, there yet remained the question of the exact nature of their forage. The results herein presented have been gathered from experiments to determine the usual and essential diet of these peculiar bugs. A solution of this problem has been attempted by feeding the insects upon surveyed mixed cultures and upon pure cultures. The former to indicate the existence of selection in their foraging, and the latter to determine if possible the essential organisms of their diet.

Thus the body of this paper consists of a report of the (*a*) history and diagnosis of the culture, (*b*) its survey, and (*c*) an analysis of stomach contents of Corixids after living within the cultures.

Technique.

In order to use due care in the manipulation of the materials the following precautions are observed: A given lot of boatmen of some species is selected and placed in clear water for a time, to remove from their bodies any foreign

matter. Now, these bugs, we will assume, have just been taken in nature. Their digestive tracts probably contain food material. A few are examined to determine this point. These are two factors at this beginning point to be considered. If the bugs have been feeding recently, the material in the digestive tract might be confused with food taken in from the food culture. Therefore the bugs must be divided into two lots. One placed in a sample of the given culture at once to serve as a check on normal (not starved) feeding, and the results observed. The other lot is then allowed to remain in the clear water for a time sufficient to clear much of the digestive tract. For this purpose fresh glass aquaria, with a few pebbles placed on the bottom to which the bugs may cling, serve admirably. This lot, then, may be placed in another jar of the culture and allowed to remain for times varying from thirty minutes, for food selection, to weeks, for determining maintenance ability of the culture. In making the examination the bugs are removed from the culture to distilled water for a few minutes. Petrie dishes do very well for this, because they are shallow. By means of the forceps a bug is caught by one of its swimming legs and placed in a drop of water on a slide. After removing its head one dissecting needle is run through the thorax to hold it in position on its venter, and the other needle dissects out the digestive tract entire. The carcass of the bug is then removed, fresh, normal salt solution passed over the digestive tract, and notes made as to the general position of the contents, whether in some part of the stomach or in the intestine. Usually there will be two masses of material. The dissecting needle pricks the stomach wall to liberate the material, which promptly speads upon the slide. The other mass is removed in the same way, then the cover slip is added and both of these smears studied under compound. Since the food is likely to be deep green in color, due to the plant chlorophyll, or at least to contain unicellular plant cells, or even bits of Spirogyra or Zygnema still containing plastids, it is convincing to make permanent mounts. To do this the smear is fixed in 8 per cent formalin to which has been added enough copper acetate crystal to give it a pale greenish tinge. This preserves the green color. The mount is then made in glycerine jelly in the usual way and sealed with asphaltum. Mounts made in this way can be used

in demonstration for a long time. For detailed studies of digestion the usual histological methods must be followed.

SPECIAL STUDIES.

Carmine Feeding.

As stated under the heading of general habits, the use of the flat palæ of the fore legs in feeding is easily observed. It occurred to the writer that if powdered carmine were sprinkled over the sediment on the bottom of the aquarium it might be taken up by the boatmen in their feeding and serve as an index to the time it takes for food to pass through the digestive tract. If found in the stomach in large quantities it would add further evidence to the belief that they scoop the food into the mouth in quantities. Several experiments and demonstrations have been made by placing the powdered carmine upon the sediment in the bottom of the jars and then turning in Corixids to feed. If hungry the boatmen will begin at once, and a dissection of one of them after ten or fifteen minutes feeding will prove that they take up the carmine and organic ooze in quantities. The digestive tracts have been found packed from end to end with the red material. On plate XXX is given a figure in color of the digestive tract of a Corixid after feeding upon carmine covered forage. Permanent mounts of digestive systems in balsam make useful slides for demonstrating this point, since the walls of the stomach become clear and the red material within gives striking preparations.

This carmine-feeding experiment was attacked from every angle in order to avoid drawing any false conclusions. A careful reading of the notes obtained will indicate how easily one could fall into errors by superficial examinations. The experiment was planned and executed by the following outline:

TYPHA CULTURE 17129.

A. Survey of culture.

B. Stender with culture and carmine.
   - *a.* Survey culture after 24 hours.
   - *b.* Place Corixids here that have been in clear water for 24 hours.
     1. Forage 1 minute and examine.
     2. Forage 5 minutes and examine.
     3. Forage 20 minutes and examine.
     4. Forage 20 minutes, remove to clear water for 30 minutes and examine.
     5. Forage 20 minutes, remove to clear water for 130 minutes and examine.

C. Check.

a. Boil some of the surveyed culture to kill organisms.

1. Place carmine over this in stender and repeat the series under B*b*.

Culture 17129 was made by grinding water-soaked leaves of dead Typha. These grindings had reached a state of balance before using in this experiment. It had been used to rear Corixids and so was known to contain the essential elements of the boatman food supply. A survey of the culture is given elsewhere, but it is well to recall that it consisted of ground-up bits of Typha tissue, a few Englenids, some Tetraspora, some algal filaments, live and dead rotifers, about equally divided, some nematode worms, and here and there various protozoans.

Some carmine was then sprinkled over a layer of this material in a stender and allowed to stand for 24 hours to note the effect of the carmine upon the animal organisms. The animals were alive and the nematodes and rotifers and some of the protozoa contained carmine, not in considerable quantities, however. One dead Oligochæta was quite strongly stained.

Adult Corixids of the species *Palmacorixa buenoi*, after 12 hours in clear water, were placed on this carmine forage, and began feeding at once. By the end of ten minutes the anterior end of the stomach of one af them was carmine red. Besides carmine grains, there were present some rotifer skins, one with red in it, open jaws of rotifers, and some green Englenids. Other specimens show the presence of considerable carmine mixed with plant matter some algæ filaments, and here and there a nematode. In all, the digestive tracts were filled with red matter, a little of which could be traced directly to the animals consumed. The colored drawing of a nematode shows one source of the carmine.

To determine whether Corixids were after live animals or would eat dead ones, too, some of the Typha was cooked. An examination showed dead rotifers and worms, etc. Added carmine to this, with the idea that the animals being dead could not ingest it. Corixids began foraging at once. An examination of their stomachs showed that they were taking up plant matter and carmine grains, also some of the dead rotifers, etc. After a few hours the dead animals had taken up the stain and in this way would account for some of the red in the Corixids,

for they continued to sweep in dead rotifers and protozoa along with green plant cells.

Spirogyra Culture.

It has been stated elsewhere in this paper that Corixids are very largely herbivorous; that the digestive tracts have been found to contain much chlorophyll. But the finding of pebbles in the stomachs of fishes is not taken as conclusive evidence that pebbles form their food supply. So with the boatmen. The writer felt that chlorophyll might be eaten by herbivores and these herbivores by Corixids, and the digestive tracts of the boatmen would be green. Moreover, even the carmine experiment cited above might be subject to criticism by those who had not made direct observations. Such skeptics might say that the carmine could be ingested by worms, amœbæ, etc., and thus, through the eating of these organisms by Corixids, get into the stomachs. The contention that Corixids are largely herbivorous, is obvious to any who repeat these experiments for themselves, but to the writer's mind, nothing seals the incontestibility of the facts like the following demonstration. This demonstration has been repeated a number of times with three or four species of Corixids. Here are the notes on the first experiment:

Washed a species of Spirogyra repeatedly in tap water until every organism perceptible under the low-power compound was removed, then placed a few filaments of this in a small Petrie dish and added an adult *Palmacorixa buenoi.* It began feeding at once and worked contentedly. It gathered up the green filaments, singly or by the half dozen, and slowly worked them backwards, using its palæ like hands, to manipulate the algal threads which it pressed to its mouth. So intent was this bug upon the business in hand, that it was content to lie upon its back and eat, so every detail visible with a high-power binocular was seen. For thirty minutes this bug fed most industriously. The spiral filament, moved from front to rear by the hand-over-hand movement of the fore limbs, was pressed to the face, the cell punctured and the green matter withdrawn. See plate XXX. Thus the threads of Spirogyra that were passed between the mouth and the palæ of the bug were transformed from threads bright with green spirals to empty and transparent filaments. After a half hour's feeding, the bug

was killed and the stomach seen to be packed with green chlorophyll. The contents of this stomach were fixed in 8 per cent formaldehyde plus copper acetate, and mounted in glycerine jelly, together with mounts of the Spirogyra before and after being foraged over by the bug. Drawings of these preparations are shown on plate XXX. The next day the experiment was repeated with two first instar nymphs of the same species. They, too, proceeded to feed at once as the adult had done.

CULTURE 16217. (Ground Elodea.)

History and Diagnosis. Ground-up tips of Elodea and changed water repeatedly to wash out the free green chlorophyll matter. Studies of the grindings show Elodea, bits of tissue and single cells. Scenedesmus, threads of Gonatozygon and Oscellatoria, diatoms, large and small, a few heterotrichs, etc.

Corixids added. Every examination made of the stomach contents of the bugs after foraging here showed the tract packed with green material. This consisted of cells of Elodea, filaments of Oscellatoria and Gonatozygon, desmids and the like. One *A. alternata* contained a thread of Gonatozygon 1 mm. long. Splendid demonstrations, all of them, of the plant feeding tendencies of these bugs.

CULTURE 17129. A. (Ground Cattail.)

History and Diagnosis. Gathered some dead cattail leaves from the marsh by the Field Station. Soaked them in water for a few days and then ground them up by means of a meat grinder. The result was a flocculent brown mass of fine matter. This material was ground up on May 9 and the water changed frequently until the 11th, when Corixids, adult and nymphs, were added. They began foraging promptly. Ten days later they were still doing nicely. Examination of the forage showed much finely divided tissue, some Algæ, mostly unicellular, such as Tetraspora and Englenæ. The rotifers, dead and alive, make up the bulk of the animals. There are plenty of the cellulose tissue of the cattail, bits no larger than the Algæ.

Corixids Added. The examination of the stomachs of the bugs always showed them filled with brownish material, superficially like the forage. A close examination, however, indicated the absence of Typha tissue, and the abundance of the ramate jaw parts of rotifers. Much brown matter that could not be analyzed, and mixed with it the green cells of the Tetraspora, Englenæ and some filamentous Algæ. Even the large *Arctocorixa interrupta* avoided taking in the Typha tissue, although it ate bits of Algæ of larger dimension. The ground Typha serves as a stock for the growth of organisms eaten by the boatmen.

CULTURE 17129 B. (Ground Cattail, sterile.)

History and Diagnosis. Same as in 17129A. Boiled this repeatedly to sterilize it. Did not use the sterilizer, however, so the ground Typha soon spoiled even if boiled.

Corixids Added The first two Corixids added refused to eat the stuff, although when placed in 17129A they began feeding promptly enough. After the material was cold and had been repeatedly washed, the bugs foraged upon it. The stomachs contained very finely divided brown matter with no animal remains. In this culture no rotifers and the like had had any chance to develop. The brown grindings, only the finest of them, were swept in directly.

CULTURE 16220 (Alfalfa base culture.)

History and Diagnosis Doctor Embody had a large circular aquarium in which he had placed ground alfalfa and a little manure. The culture had reduced itself to a spongy mass in the bottom and the water was fairly clear, with duckmeat growing on top. The plant life is largely Oscillatoria, diatoms, etc. present also.

Corixids Added. Bugs were kept here for more than a month, and did very well. Their stomachs were always full of dark green material, which often consisted of great skeins of Oscillatoria filaments and little else. In some of them this blue-green could be traced from fresh material in the fore part of stomach to broken up, disorganized particles in rectal pouch.

CULTURE C. (Bran.)

History and Diagnosis. Ground-up bran.

Added Corixids. This experiment was not a success at all. Fermentation made life untenable for the bugs.

CULTURE 16221. (Euglenæ.)

History and Diagnosis. A large rectangular aquarium. The bottom contained sand and the aquarium had been in use a long time. A green growth covered the sides and bottom. The water itself was green, due to millions of Euglenids!

Corixids Added. A great many Corixids were placed here and afterwards examined. Their stomachs were packed green with Euglenids and little else!

CULTURE 179. (Largely Mougeotia.)

History and Diagnosis. A large aquarium jar had been sitting beneath a constantly running tap. It contained quantities of oozy material, having a brownish tinge. This consisted of diatoms, Scenedesmus, Gleocapsa and Mougeotia filaments. The last the dominant organism.

Corixids Added. Examination of Corixids after feeding here proved that they were consistently gathering the Mougeotia after their stomachs were packed with it.

CULTURE 17143. (Mougeotia.)

History and Diagnosis. Placed sand in the bottom of a large rectangular glass jar. Added some green material from a jar in Doctor Embody's office.

Corixids Added. After a couple of weeks added a number of fifth-instar nymphs of *P. buenoi* and some adult *A. alternata.* After a couple of days examined the stomach contents of the bugs. In every case the

tract was packed with pale green matter like the culture! This proved to consist almost exclusively of the clear filaments of Mougeotia, the contents of the cells of which were in a state of disintegration. The free granular green matter was obviously derived from contents of the Mougeotia cells. No animal organisms or their remains found in these examinations.

CULTURE 16126. (Rivularia.)

History and Diagnosis. A porcelain-lined, granite-ware pan, which had been used for some time as a watering vessel for the birds and chickens, contained a layer of brownish material over the bottom and up the sides. Upon examination the material was found to consist of debris and *Rivularia natans*, no animals present.

Corixids Added. Eggs of an undetermined Corixid were added and reared to second instar, when all died. The experiment was repeated with similar results. The water was not changed as frequently as might have been desired. Adults of *R. acuminata* and *A. alternata* failed to live more than a few days in this culture.

CULTURE 1754. (Slime Diatoms.)

History and Diagnosis. The rocks of upper Fall Creek were covered with long, brown strings of gelatin in March. This was found to consist of great quantities of the diatoms, Meridion, Fragilaria, etc., some filamentous Algæ present but scattered. Placed some small stones, coated with this material, in a battery jar.

Corixids Added. Placed Corixids here and they promptly began feeding. When examined surprisingly few diatoms were present, but quantities of filamentous algæ, Mougeotia and Zygnema.

For example, one female *A. alternata* had the fore part of the stomach packed with filaments of Zygnema as long as the entire mid intestine. This series shows selection in favor of the filamentous algæ with discrimination against the gelatin embedded diatoms.

CULTURE 17144. (Ankistrodesmus.)

History and Diagnosis. Removed the gold fish from a jar in which they had lived for a long time. The jar and rocks were covered with dark-green growths. The water was very green. This was replaced by fresh water. The green growth was dominantly *Ankistrodesmus falcatus.* Some Scenedesmus and diatoms present as well as Cosmarium and Tetraspora.

Corixids Added. Twenty nymphs of P. buenoi added. Examined their stomach contents from time to time and they were always full of green chlorophyll material with *Ankistrodesmus* dominant and other Algæ present with an occasional rotifer. Green plants are taken first hand and in quantities.

CULTURE 16169. (Botryococcus pure.)

History and Diagnosis. Botryococcus (a little alga in gelatin.) This culture was pure and growing in Knap's solution.

Corixids Added. The bugs always died within a day or so.

CULTURE 16168. (Oscillatoria.)

History and Diagnosis. Pure culture of Oscillatoria obtained from water analysis laboratory. No animals in this culture.

Corixids Added. Placed *A. alternata* here July 28. On August 1 they were observed to work at food gathering. August 8 dissected the Corixids:

One male. Digestive tract nearly empty. A brown mass of indeterminate material in bend of mid-gut.
Three females. Tracts nearly full of reddish brown material, indeterminable.
One male. As above, plus considerable number of Oscillatoria filaments, some of them still well preserved.

CULTURE A, AUGUST 19. (Green pond ooze.)

History and Diagnosis. Gathered some shiny, greenish ooze from the bottom of a mud puddle. This contains various species of Algæ, especially the blue greens, and among the free moving Englenæ and diatoms.

Corixids Added. Several specimens of a small species of Corixid added. In twenty-four hours examined them. Their stomachs were packed with green matter. This consisted of much disorganized unicellular plant cells, Oscillatoria filaments so abundant that they bound the masses together, Englenæ and diatoms. This one study would satisfy one beyond any question of a doubt as to the plant origin of their food.

CULTURE B, AUGUST 19. (Water Bloom muddy.)

History and Diagnosis Gathered some of the green scum from a stagnant, muddy pool and placed it in a Petrie dish.

It was teeming with life. Plants: Chlamydomonas, small species of Englena, large species Englena, diatoms, some Oscillatoria, and a few filaments of an alga. Englena dominant. Animals: Arcella abundant for this genus, Amœba stuffed green with ingested unicellular plants. A few Paramecium and Heterotrichs.

Corixids Added. A. alternata and *R. acuminata* placed upon this culture. Examined following day. 3 ♀ *R acuminata* nearly empty. Another contained a small ball of yellowish green material in the bend of the mid intestine. This was dissected out entire and resisted separation as if held together by fibrous material. Most of this mass was disorganized unicellular plant particles, such as noted in the Amœba. Two clear shafts of some filamentous algæ and a membrane of some Crustacea and *A. alternata* mid-intestine packed full of green material, which resisted separation like the above. Mostly bits of greenish material, parts of unicellular plants, many encysted, plenty of bright green cells nearly circular in outline. Red spots of material from disorganizing Englenæ. Two filaments of Oscillatoria, a couple of diatoms. Most material is of Englena origin, as shown by the fact that fresh Englenæ still green are abundant, and all stages of disorganized material are to be found. Thus the yellowish granular material can be traced to its unicellular plant origin.

CULTURE 17165. (Chironomus.)

History and Diagnosis. Early in the studies on the boatmen, it was found that hungry bugs would eat Chironomus larvæ. In this experiment some sand grains were placed in the bottom of a stender dish, and six Chironomus larvæ added.

Corixids Added. Placed six *P. buenoi* here that had been in clear water two days. In two hours only three Chironomus larvæ remained. These were fortified beneath sand grains. These midge larvæ live in the sludge where Corixids forage. They live in tubes of their own spinning, and occasionally are eaten by the boatmen when the bug comes upon them in the course of its feeding.

CULTURE 1650. (Balanced Aquarium.)

History and Diagnosis. Into a circular glass aquarium jar, 9½ x 8 inches, there had been placed about May 1 one of the Characeæ (Nitella) and some clear pond water. The culture came under observation the latter part of May, at which time the Nitella was still a thriving plant, and a small quantity of brownish sediment was upon the bottom of the jar (arranged in a ring perhaps two inches broad around it). The container was kept nearly full of water by additions from the top. Corixid nymphs in their first instar had hatched from eggs brought in on the Nitella, and continued their development till they became adults. Bits of the carapace of a crayfish bearing eggs of *Ramphocorixa acuminata* were then added, and this species brought to adult stage. This culture then has considerable interest from the fact that two generations of Corixids were reared in it, one of *A. alternata,* a clear-pool type, and one of *R. acuminata,* a stagnant-pool type.

The Nitella gradually disintegrated, adding its parts to the deposits in the bottom of the jar, until by July 23 little was left of it. Surveys from time to time disclosed the following in the deposits: Much disorganized plant matter, a few green spores of Algæ, slender empty filaments of Algæ, some Pediastrum, various diatoms (abundant), and now and then the shell of an Ostracod. Ostracods and snails the only forms of animal life noted. The sediment, notably clear of animal life, adds another feature to the interest of this study. Corixids were observed repeatedly to feed upon the brownish deposit. Corixids were maintained in this jar continuously for nearly four months.

Corixids Added. Corixids of two species, *A. alternata* and *R. acuminata,* were reared here. Some of the bugs were maintained here for four months. These bugs obtained their food from the deposits at the bottom. They did not prey upon the Ostracods feeding upon the sides of the jar.

CONCLUSION.

After carefully checking the results of feeding experiments it is safe to note the following:

Corixids sweep in the organic ooze of the pool with its attendant populations, both plant and animal, the bulk of the

material being of plant origin. The presence of long filaments of Spirogyra, Zygnema and Oscillatoria cannot be accounted for in any incidental manner. The deliberate action of the bug in feeding on the chlorophyll of Spirogyra, as indicated above, is conclusive evidence of the herbivorous tendencies of these creatures. The presence of oligochætes, nematodes, rotifers and protozoa indicates that they consume the little animals along with the plant matter. As a basis for the propagation of Corixids in artificial quarters, it has been discovered by experiment that a satisfactory food supply can be obtained by grinding the water-soaked leaves of cattail that have laid in the marsh over winter and allowing them to reach a state of balance. A brown flocculent mass is thus produced, in which develop a flourishing population of tiny organisms, both plant and animal. In such a culture *Palmacorixa* has been carried from egg to adult.

General Review.

In the pages preceding an attempt has been made to present the most important points now known about the biology of water bugs. It has been arranged to most readily determine what is known on any given form. To facilitate future work, the sexual differences of the various groups are figured. These, together with the drawings of the nymphs, permit a ready analysis of a survey of the pond at any time. The general reader is referred to the chapters on Ecologic and Economic Relations, and Form and Function, for matters of popular interest.

In the developmental studies there have appeared certain points of note. The developmental changes of these bugs fall into two categories: First, characters acquired by the adult; second, characters lost by the adult.

Under the first may be mentioned the fact that ocelli, as a rule, when present at all, are adult characters. The toad bug is an exception to this, the nymphs possessing ocelli. The tarsus when two or three segmented is usually an adult character, the nymphs having one-segmented tarsi. Sometimes the adult possesses more segments in the antennæ, as in Corixids. The sexual dimorphism of the adults, such as the asymmetry of male Corixids, etc., is, of course, attained only in the adult.

On the other hand, in some instances of adaptation the adults lose structures present in the nymph. The best illustration, perhaps, is that of the Belostomatids, which have a single claw on front tarsus. The nymphs have two, one of which may get relatively smaller as later instars are reached. Another case is that of the hind claws of Notonecta and the Corixids. The first instar nymphs have two long claws, while those of adult are setaform and obscured by the swimming fringe. These various changes are fundamental and significant. In determining phylogenetic relationships, the internal organization, combined with developmental changes, are most important in forms with incomplete metamorphosis. No staple arrangement of the Heteroptera can be made until much more is known of the biology of the group.

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ERRATA.

In the survey of families of Hemiptera place the "Fulgoridæ" with the "Auchenorhyncha."

Page 19, line 19. "Rawlins" instead of "Rawline."

Page 30, line 10. "Gerridæ" instead of "Veliidæ" (above Genus Halobates).

Page 108, line 30. Insert "*G. remiges*" after the statement following C.

Page 121, line 46. "Obsolete" instead of "obselete."

Page 127, line 1. "Microvelia marginata, Uhl."

Page 142, line 15. "Belostomatidæ."

Page 157, line 37. "Is" instead of "are."

Page 173, line 21. "Genus Buenoa, Kirkaldy."

Page 181, line 7. "Genitalia."

Page 243, line 37. "Color Plate I" instead of "Plate XXX."

Page 244, line 6. "Color Plate I" instead of "Plate XXX."

Description of Plates.

PLATE I.

KANSAS PONDS.

PHOTO I. Smith Pond, a muddy pasture pond, frequented by cattle. Here *Buenoa* was dominant in midsummer.

PHOTO. II. The large barren Brick Plant Pool, clay bottom and clay sides, no vegetation and few insects.

PHOTO. III. Rock Pool, a small temporary pool in which *Notonecta undulata* is dominant in early spring. They show as black specks upon the water in the photograph.

PHOTO. IV. Another view of Brick Plant Pool.

PHOTO. V. Bismarck Grove Pond, a permanent pond, suitable for winter quarters, but containing too little vegetation for many aquatic bugs. A few Belostoma were taken here.

PHOTO. VI. A small pond at brick plant. This pond is overgrown with willows and cottonwoods. The bottom is thickly strewn with leaves and brush, ideal winter quarters for many bugs.

PHOTO. VII. Cattail Pool from the west end. This end is invaded by cattail. The water here is six inches to a foot deep.

PHOTO. VIII. Cattail Pool from the south. The invading cattail on left. Here is the home of Hydrometra. Upon the floating Spirogyra are found Hydrometra, *Microvelia borealis* and *Mesovelia mulsanti* in great numbers. *Gerris marginatus* is here and there upon the surface. This temporary pool lies in a rock quarry and dries up in midsummer.

PLATE I.

PLATE II.

Upper picture shows the Smoky Hill river valley in Wallace county, Kansas.

The lower photo is a close view of the Smoky Hill river in its sandy bed (Wallace county). The stream is "up" somewhat.

PLATE II.

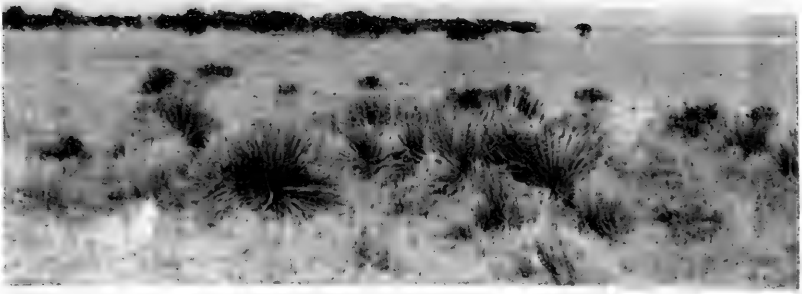

PLATE III.

FIG. 1. Side view of Corixid clinging by his long middle legs to a grass stem in the water. (This and the other pictures on this plate were photographed from life.)

FIG. 2. Corixid clinging to a vertical support in the water.

FIG. 3. Corixids in water on horizontal support.

FIG 4. *Belostoma fluminea* feeding upon dragon fly nymph.

FIG. 5. Characteristic position of *Belostoma fluminea* upon a support in the water, awaiting the approach of prey.

PLATE III.

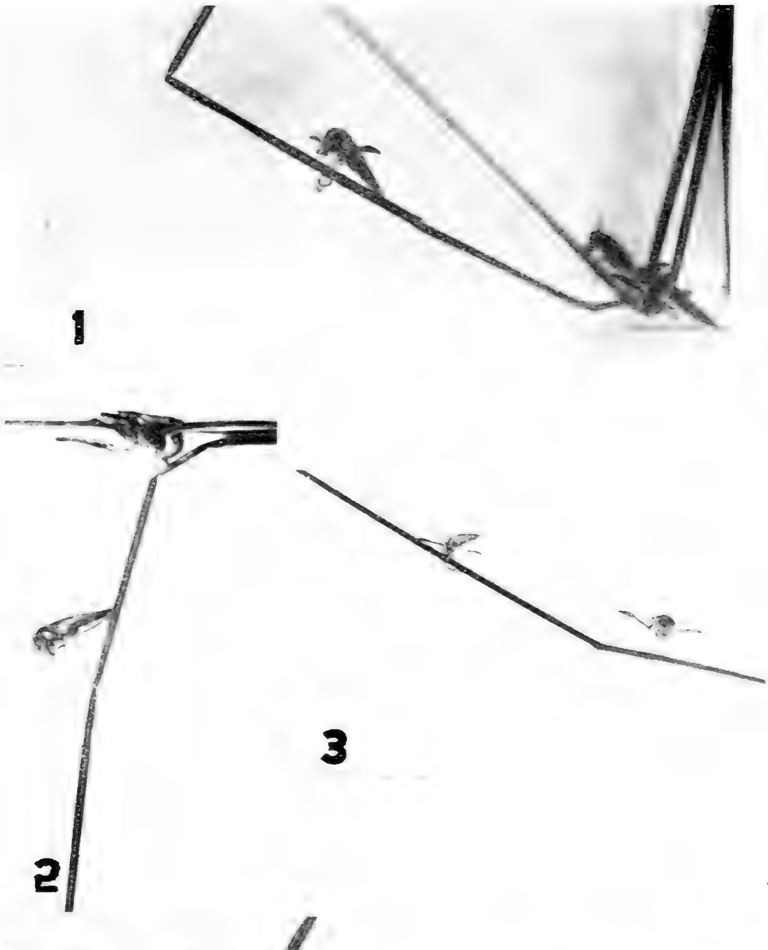

PLATE IV.

TAB. XIII. Back-swimmers: adults and nymphs.

TAB XV. Nepa.

TAB. XVI. Ranatra.

TAB. XIV. Naucorid. The above are photographs of the plates in Frisch, an old text published in 1727. Among the first published illustrations of water bugs. (Not the first, however.)

PHOTO. 1. The toad bug resting upon sand.

PHOTO. 2. Ventral view of female Corixid. Note the peculiar beak and remarkable differentiation of the limbs.

PHOTO. 3. *Notonecta undulata.* Say.

PHOTO 4. *Buenoa margaretacea.* Bueno.

PHOTO. 5. Female Corixid—*Ramphocorixa acuminata.* Uhl.

PLATE IV.

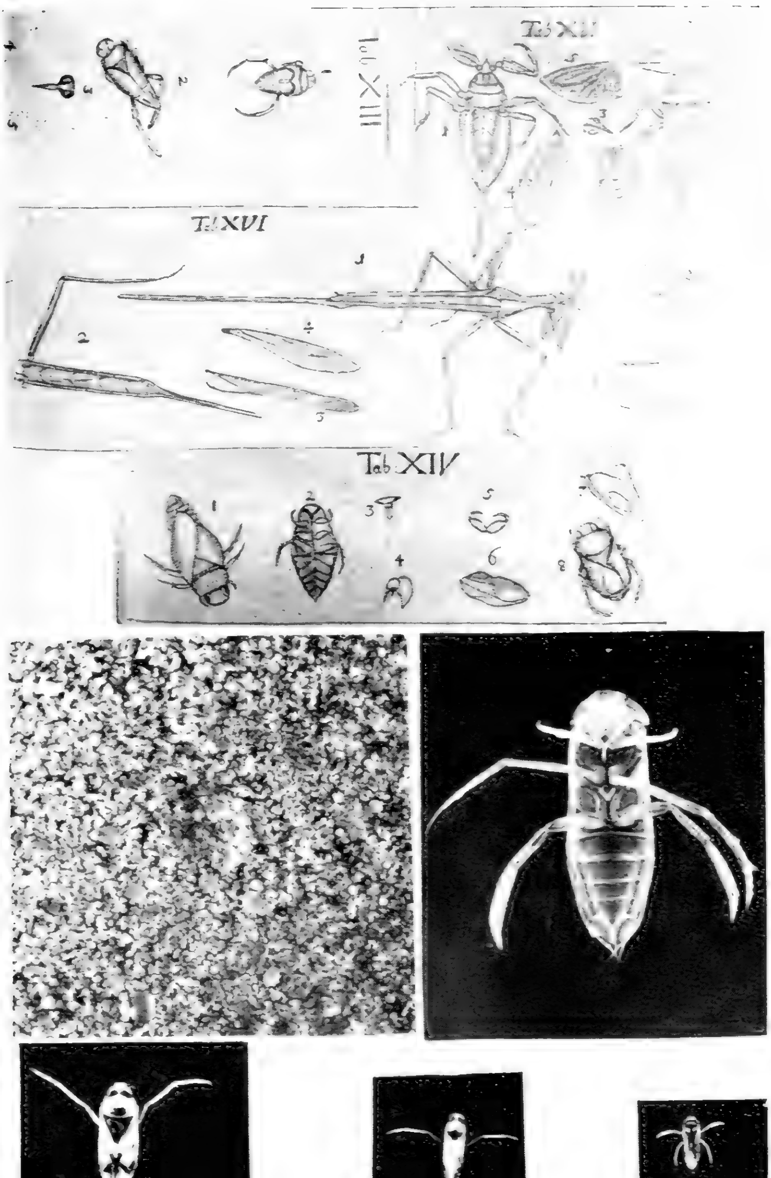

PLATE V.

PHOTO. 1. Ventral view of a toad bug, *Gelastocoris sp. new*, showing him in possession of three lace bugs (Tingididæ). (Bug from Larned, Kan.)

PHOTO. 2. Ventral view of another bug of the same species with a Mirid (Capsid).

PHOTO. 3. The marshtreader, *Hydrometra martini*, from the Cattail Pool at Lawrence, Kan.

PHOTO. 4. The end of a battle—photograph of *Nepa* and *Ranatra*. These bugs were placed in a jar of water without supports and *Nepa* proved to be the better able to control himself. (Ithaca, N. Y.)

PHOTO. 5. Photograph of *Salda anthracina* from the bog pond, Ringwood Hollow, near Ithaca, N. Y.

PLATE V.

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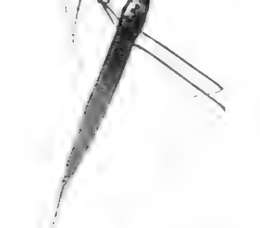

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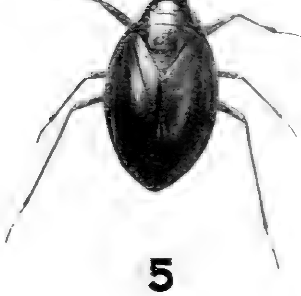

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PLATE VI.

FIG. 1. Eggs of *Salda authracina* in bog moss.

FIG. 2. Photograph of egg of *Hydrometra martini.*

FIG. 3. Eggs of *Lamprocanthia crassicornis* at the base of shore grass.

FIG. 4. Microphotograph of the egg of *Hydrometra* attached to a sprout of cattail. Two sprouted seeds of cattail are shown. Note the superficial resemblance.

FIG. 5. *Gerris* eggs laid in nature on the underside of grass blade floating out upon the water. On the upper grass blade the eggs have hatched. Note the longitudinal rent.

FIG. 6. Eggs of *Gerris marginatus* on upper surface of leaf blade in an aquarium containing very little water.

PLATE VI.

PLATE VII.

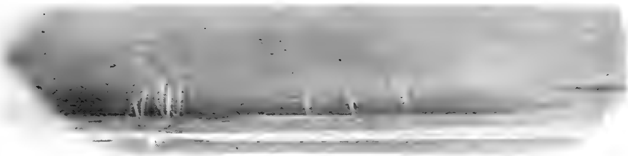
EGGS OF RANATRA.

I. Photograph of *Ranatra* eggs in cattail leaf. The lower part of the leaf has been removed to show the eggs.

II. Photograph of cattail leaf containing eggs of *Ranatra*.

III. Close view of the one shown in I.

PLATE VII.



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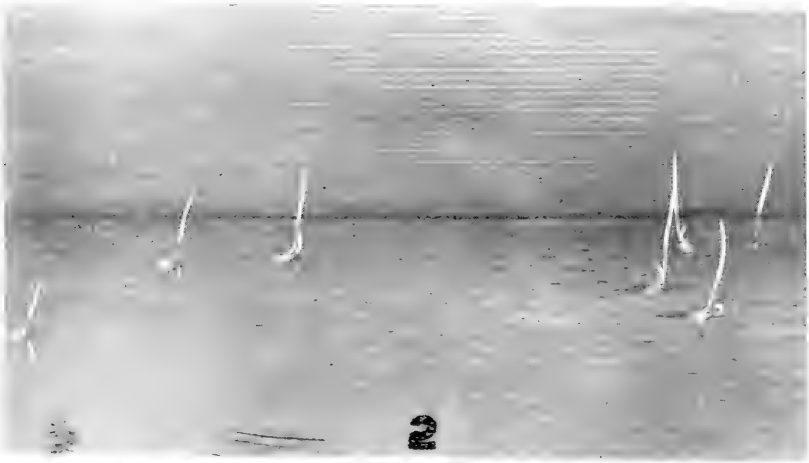

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PLATE VIII.

PHOTO. 1. Eggs of *Notonecta irrorata* inserted in the stem of moneywort.

PHOTO. 2. Egg of *Notonecta undulata* on edge of cattail leaf.

PHOTO. 3. Eggs of *Notonecta insulata* on *Chara.*

PHOTO. 4. Eggs of two species of Notonecta *N. insulata* above, *N. variabilis* below.

PHOTO. 5. Corixid eggs on a submerged twig. They are often much more abundant than this. The twig here photographed was a part of a six-foot branch covered throughout. The twig is a fair sample.

PHOTO. 6. Egg of Corixid enlarged.

PLATE VIII.

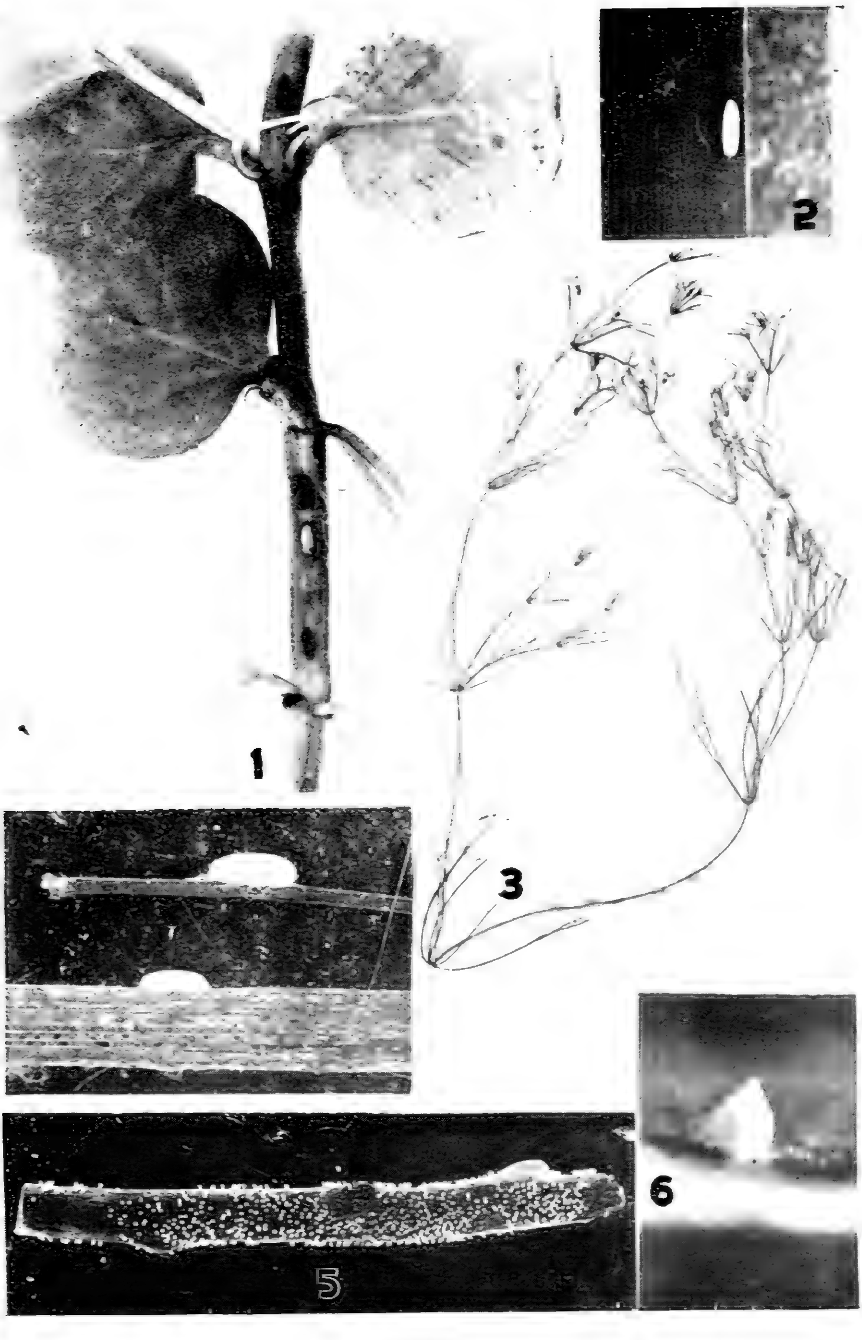


PLATE IX.

GELASTOCORID AND NAUCORID.

FIG. 1. Ventral view of *Gelastocoris*, female.

FIG. 2. Antenna of Saldid. Note the extra intersegments.

FIG. 3. Egg of *Gelastocoris sp. new.*

FIG. 4. A bit of chorion of the egg shown in figure 3.

FIG. 5. Ventral view of female ovipositor of *Gelastocoris*

FIG. 6. Ventral view of abdomen of male *Gelastocoris*. Note asymmetry.

FIG. 7. Ventral view of ovipositor of *Pelocoris carolinensis*.

FIG. 8. Ventral view of abdomen of female *Pelocoris carolinensis*.

FIG. 9. Ventral view of abdomen of male *Pelocoris carolinensis*.

PLATE IX.

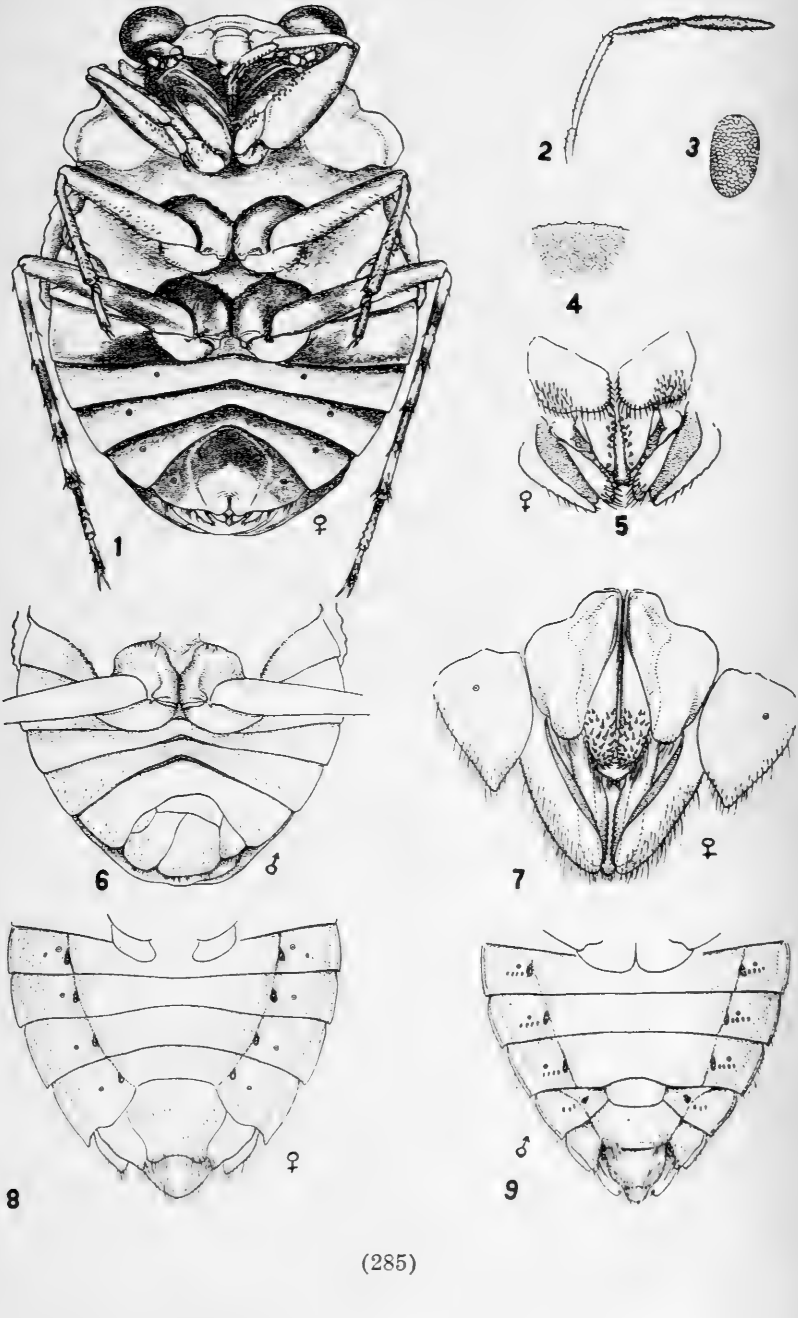


PLATE X.

FIG. 1. *Hebrus concinnus*, ventral view of male abdomen.

FIG. 2. *Hebrus* egg partially dissected from bit of moss. Egg shows the red eye spots of embryo within.

FIG. 3. *Hebrus*, ventral view of abdomen of female. (Drawings 1, 2, 3, made to same scale. Note the relatively large size of the egg.

FIG. 4. *Hebrus* eggs in loose leaved moss, showing attempt to conceal by fastening the tip of one leaf to the one above it, with some gelatinous material.

FIG. 5. *Hebrus* egg freshly laid, surrounded by the hyaline tissue of a moss leaf.

FIG. 6. *Lamprocanthia crassicornis,* egg *in situ* between the leaves of moss.

FIG. 7. *Salda anthracina* egg, same scale as figures 6 and 7.

FIG. 8. *Hebrus* egg *in situ* between the leaf and stem of close growing moss.

FIG. 9. *Lamprocanthia crassicornis,* ventral view of abdomen of male.

FIG. 10. Clump of sedges showing eggs of *L. crassicornis* in situ.

FIG. 11. *L. crassicornis* egg. Compare with figure 7.

FIG. 12. *L. crassicornis,* ventral view of abdomen of female.

PLATE X.

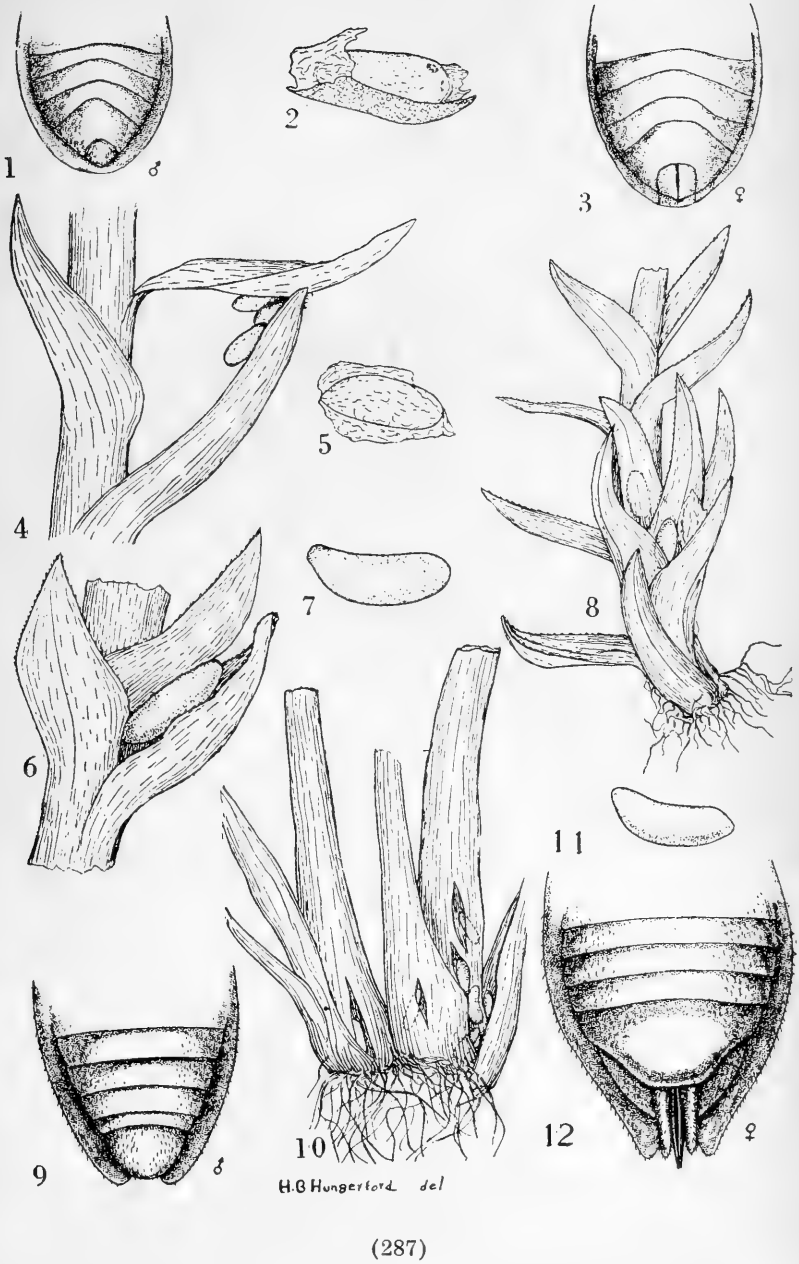


PLATE XI.

HEBRUS AND RHAGOVELIA.

FIG. 1. Adult female *Hebrus concinnus.*

FIG. 2. Antennæ of *Hebrus* to show the five segmented condition plus the small segments.

FIG. 3. First Instar nymph of *Hebrus.*

FIG. 4. Fore and hind wings of *Hebrus.*

FIG. 5. Female *Rhagovelia obesa.*

FIGS. 6 and 7. Tarsus of middle leg to show the cleft condition with its tuft of fringed hairs. These spread beneath the surface of the water, as in 7, and aid in rowing over rapid water.

FIG. 8. One of the fringed hairs enlarged. (6, 7 and 8 from Bueno.)

FIG. 9. Male *Rhagovelia obesa.*

PLATE XI.

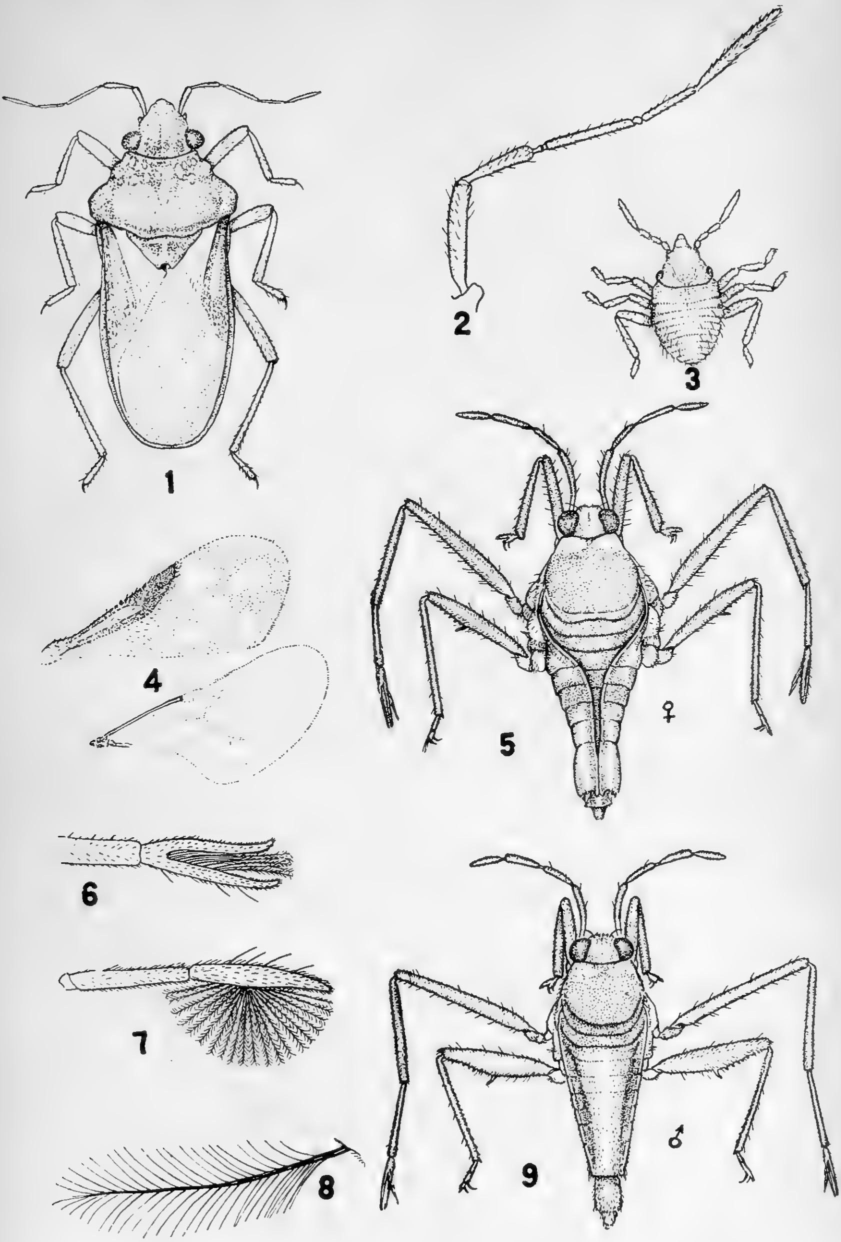


PLATE XII.

MICROVELIA BOREALIS.

1. A single egg in its mass of adhesive material.
2. First instar nymph.
3. Second instar nymph.
4. Third instar nymph.
5. Adult apterous female.
6. Molted skin of third instar nymph.
7. Adult apterous male.
8. Last instar nymph.
9. Adult male winged. (Determined by Bueno, but does not show curved hind tibia.)
10. An egg shortly before hatching. The embryo usually lies with its dorsal surface to the support. The hatching device shows between the eyes.
11. Female winged.

PLATE XII.

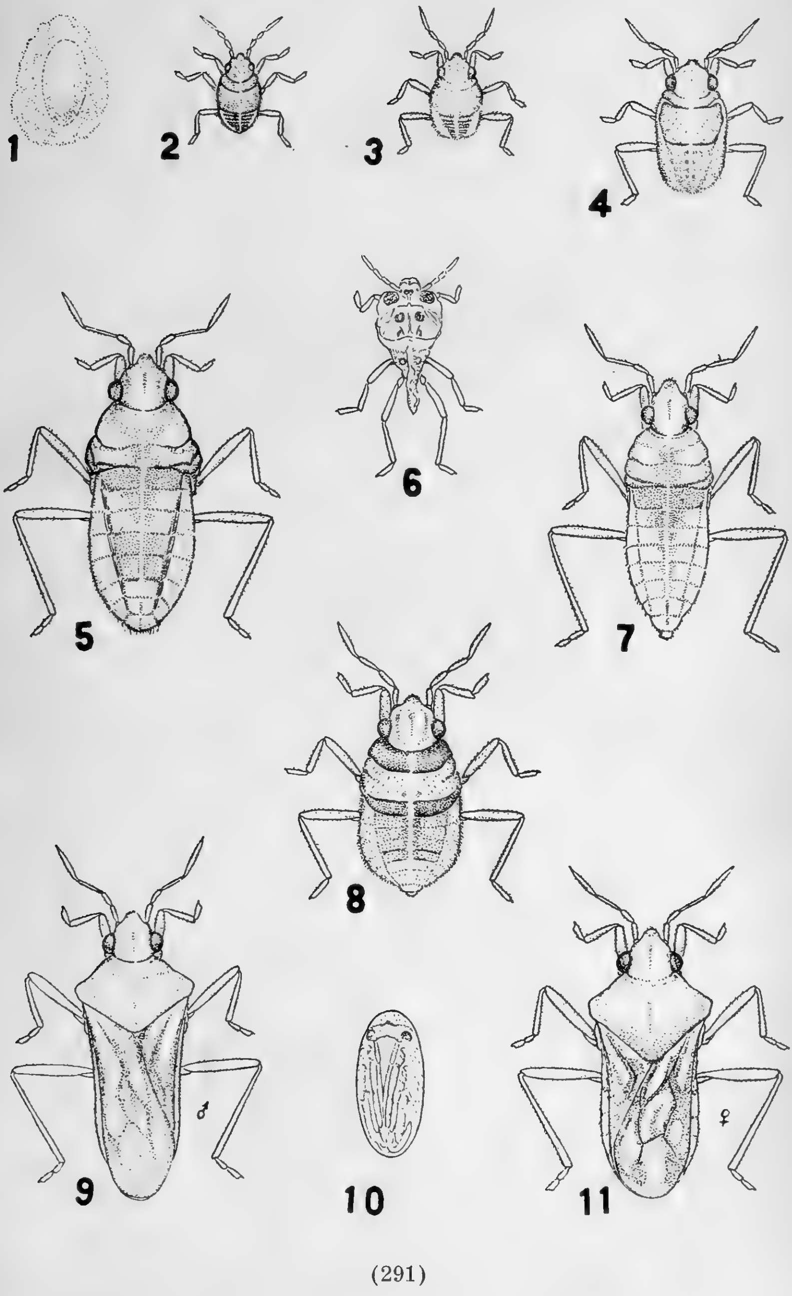


PLATE XIII.

HYDROMETRA MARTINI.

FIG. 1. Second instar nymph.

FIG. 2. Third instar nymph.

FIG. 3. Fourth instar nymph.

FIG. 4. Fifth instar nymph.

FIG. 5. First instar nymph.

FIG. 6. Egg of *Hydrometra martini.*

FIG 7. Hatching Hydrometra. *H.*, hatching device on post-natal molt; *a*, coiled stylets; *c*, labrum; *b*, beak; *d*, antenna; *e*, legs.

FIG. 8. Ventral view of abdomen of male *Hydrometra martini.*

FIG. 9. Side view of same.

FIG. 10. Hatching Hydrometra. Note the hatching device between the eyes.

FIG. 11. Foot of Hydrometra.

FIG. 12. Side view above. Dorsal view below of *Hydrometra australis.*

FIG. 13. The same for *H. martini,* after Bueno.

FIG. 14. Female Hydrometra, ventral view.

FIG. 15. Ventral view of female abdomen. Cleared in cedar oil. Shows egg.

PLATE XIII.

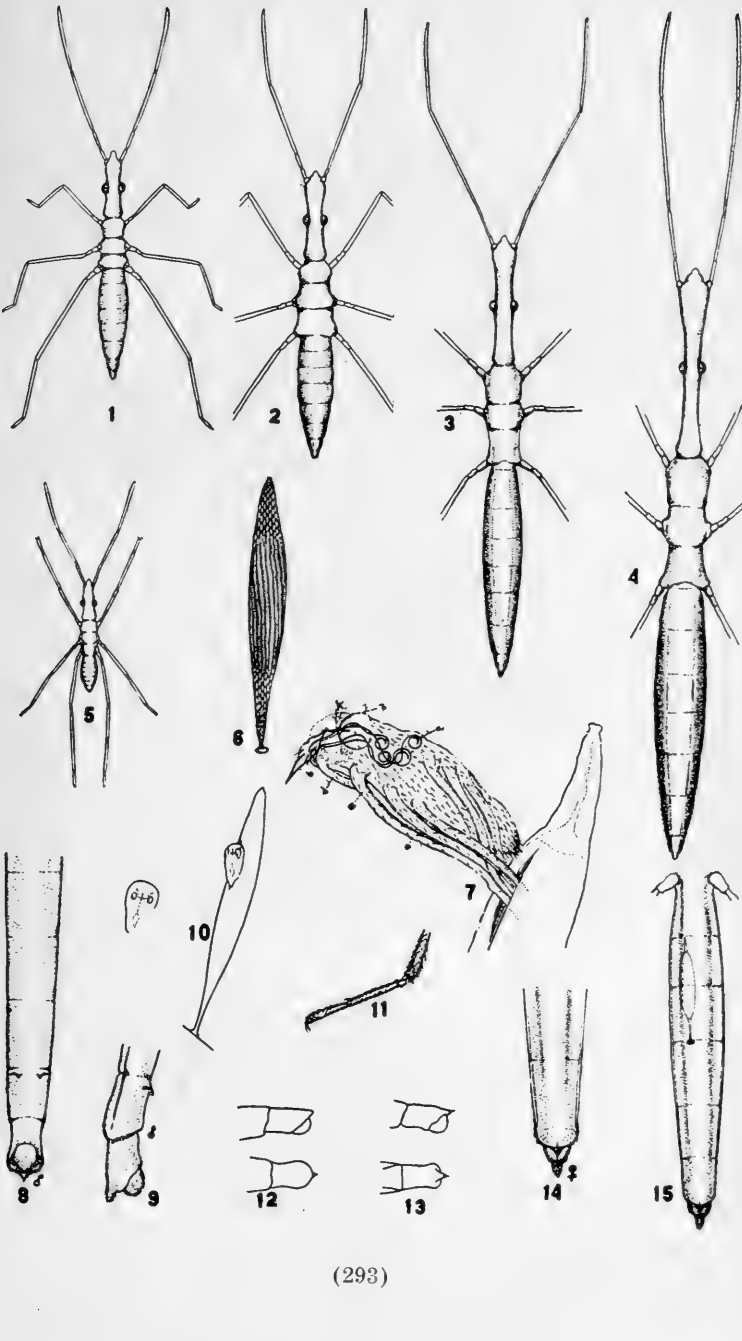


PLATE XIV.

MESOVELIA MULSANTI.

FIG. 1. *Mesovelia mulsanti,* winged male with membrane of wings broken off.

FIG. 2. *Mesovelia mulsanti,* winged female, wings entire.

FIG. 3. Fifth instar nymph; note the dorsal pore on fourth abdominal segment.

FIG 4. First instar nymph.

FIG 5. Eggs in stem of sedge, surface view of the two at left. The other two seen in situ in stem when portion of stem is removed.

FIG 6. Fourth instar, apterous form.

FIG. 7. Two eggs, showing their connection with surface of stem; eye spot shows in the one to the right.

FIG. 8. The embryonic membrane, cast by the hatching nymph; 2 "pegs" shown at the left enlarged.

FIG. 9. Apterous male.

FIG. 10. Apterous female.

FIG. 11. Male genitalia from above.

FIG. 12. Male genitalia from side, hooks in black.

FIG. 13. Ventral view of female ovipositor in its sheath.

FIG. 14. Ovipositor lateral shafts shaded. They slide up and down on the central shaft.

FIG 15. Cephalic view of ovipositor, turned into position for action. Plate first appeared in Psyche XXIV.

PLATE XIV.

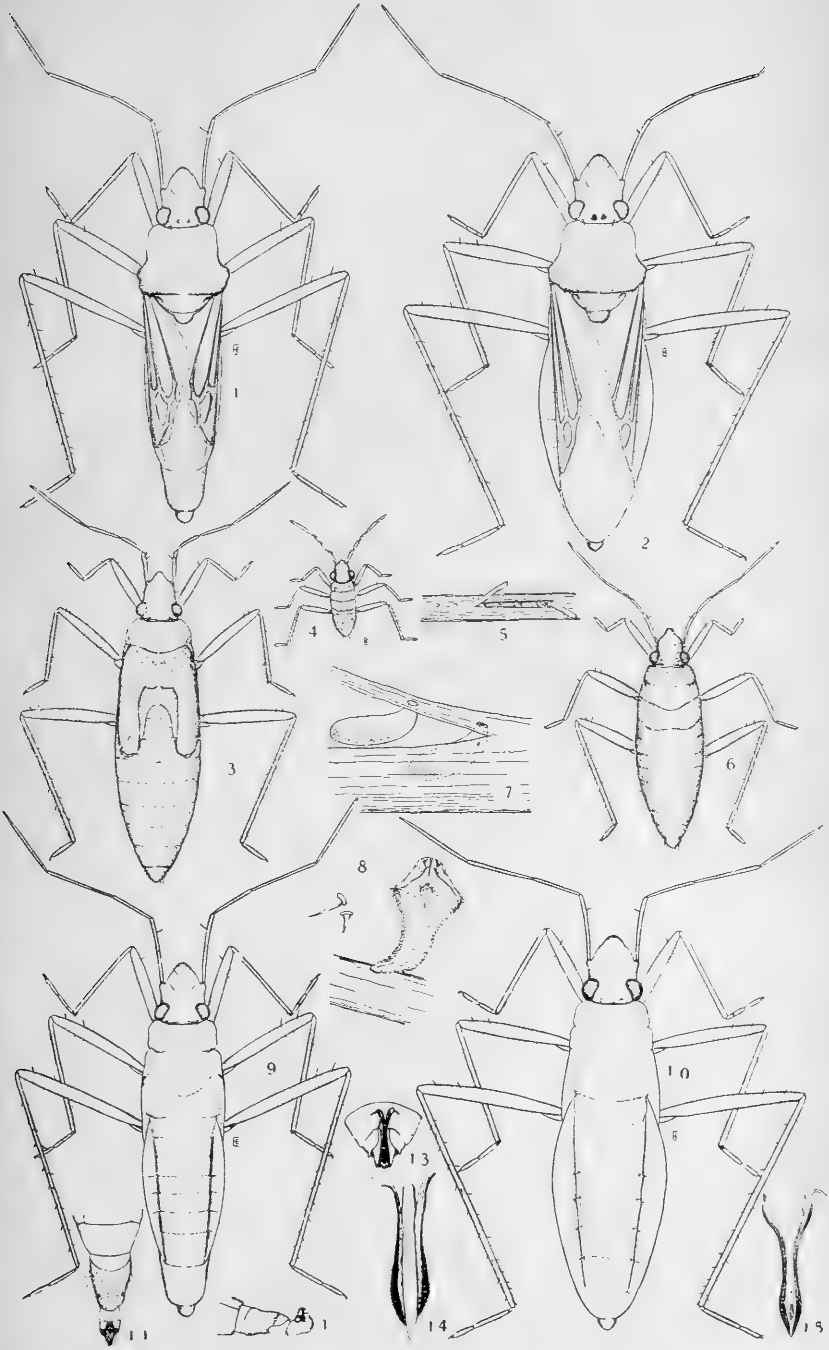


PLATE XV.

GERRIS AND TREPOBATES.

FIG. 1. Hatched egg of *Gerris marginatus*, showing the postnatal molt and the black chitinous "egg burster."

FIG. 2. First instar nymph of *G. marginatus*.

FIG. 3. Nymphal molt of *Gerris*.

FIG. 4. Front foot of *Gerris*

FIG. 5. First instar nymph of *G. remigis*.

FIG. 6. Ventral view of male *Gerris*.

FIG. 7. Dorsal view of male *Gerris*.

FIG 8. Ventral view of female *Gerris*.

FIG. 9. Dorsal view of female *Gerris*.

FIG. 10. Mating *Gerris*.

FIG. 11. Eggs of *Trepobates pictus* on under surface of floating duckweed. (Lemna.)

FIG. 12. First instar nymph *Trepobates pictus*.

FIG 13. Egg ready to hatch. Note the "egg burster" between the eyes. The small spots are red as well as the eyes.

FIG. 14. Eggs of *Trepobates pictus* on underside of leaf blade. Note the gelatinous matrix. If disturbed the entire mass comes from the leaf intact.

PLATE XV.

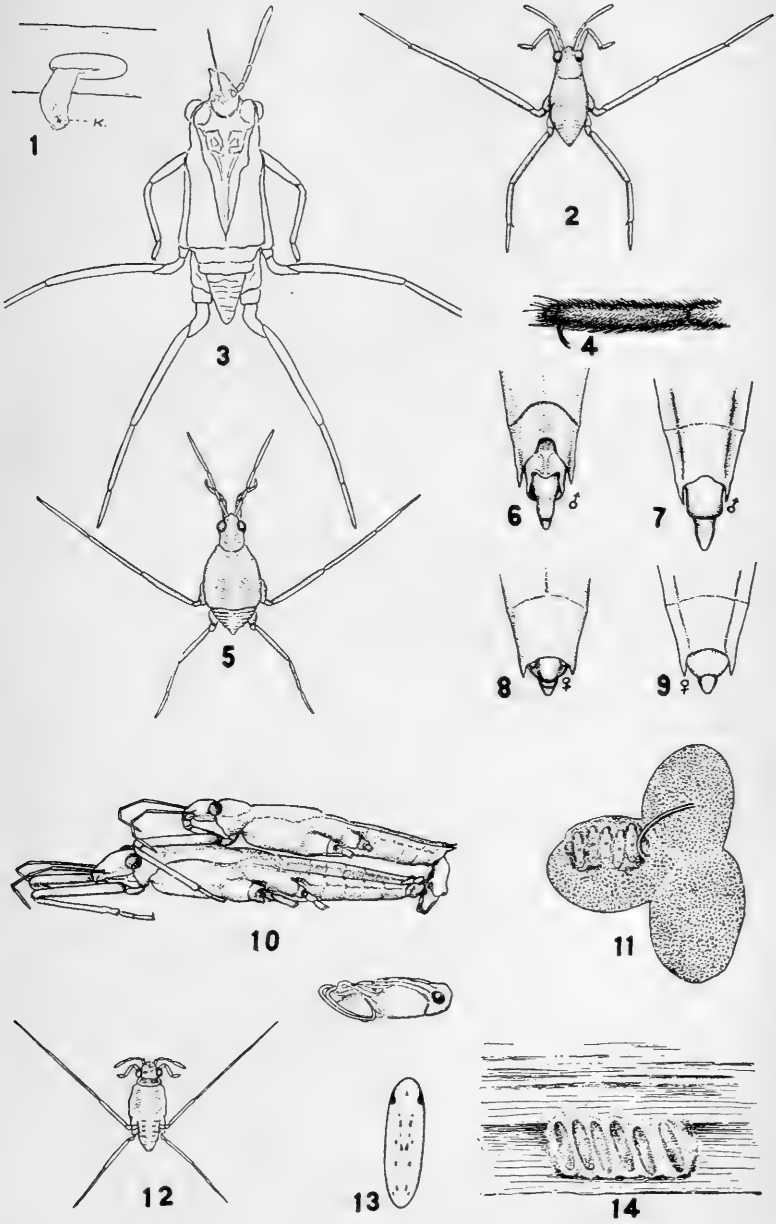


PLATE XVI.

RHEUMATOBATES RILEYI.

Fig. 1. Ventral view of male. Note the peculiar formation of antennæ and hind femora.

Fig. 2. Antennæ of female.

Fig. 3. Fore leg of Rheumatobates, inner view.

Fig. 4. Dorsal view of tip of abdomen of female, dorsal abdominal wall removed to expose the base of the ovipositor.

Fig. 5. The ovipositing device partly dissected.

Figs. 6 and 7. Left side view of one of the drill parts.

In Figures 4 to 7 the same letters are used to designate like parts.

a. Dorsal abdominal plate.
b. Ventral broad flat valve employed as sheath to the drill parts.
c. The drill parts, flattened chitinous structures grooved to slide within *d*.
d. Upper part of ovipositor parts. The heavily chitinized braces are shown at *e*.
e. The chitinous braces of the dorsal pair of ovipositor parts.

The ovipositor is made up of three pairs of shafts, a ventral broad flat pair serving as shields (*b*). These are attached at their upper end to (*c*), the drilling parts which are strongly chitinized thin plates grooved to slide within (*d*). Between the dorsal valves (*d*) is a membrane which forms the dorsal wall of the egg tube. This is attached to (*i*).

Fig. 8. Dorsal view of abdomen of female showing ova. There were eight well-developed ova.

Fig. 9. Egg of *Rheumatobates rileyi*.

PLATE XVI.

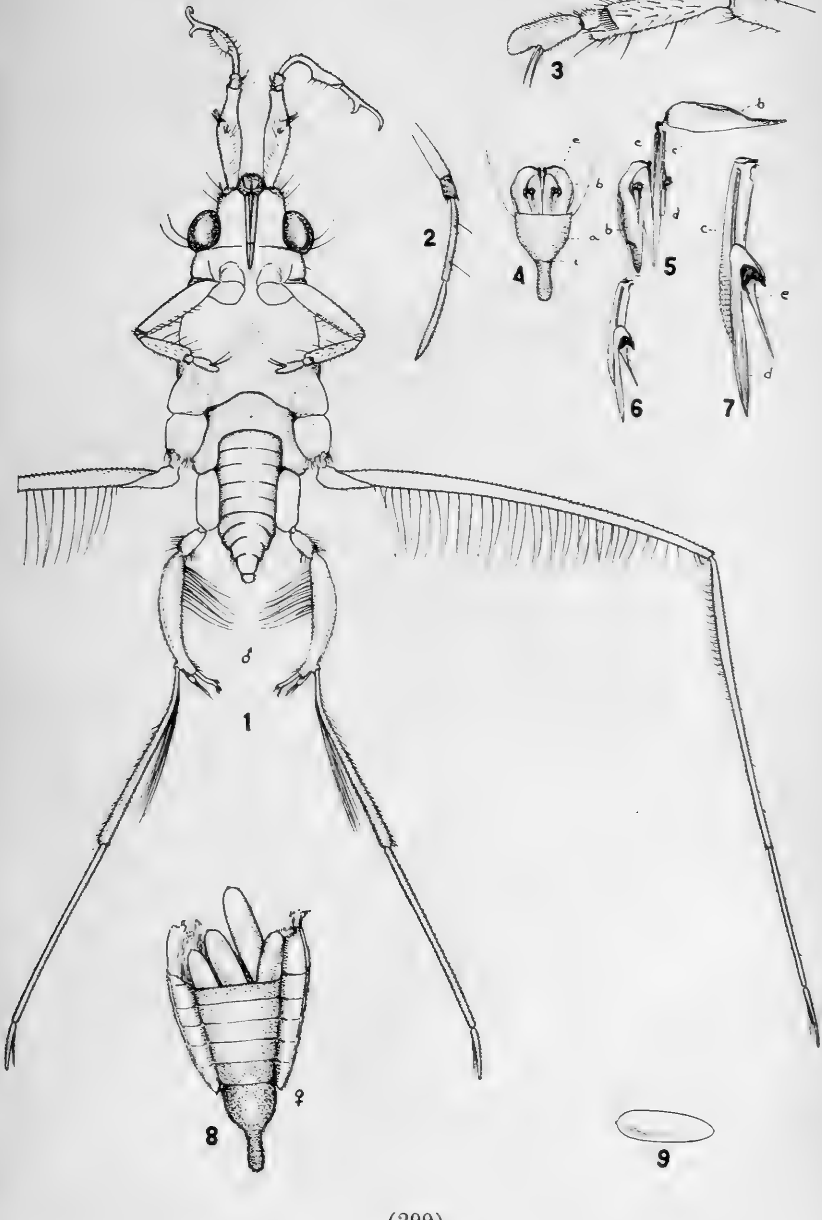


PLATE XVII.

BELOSTOMA.

FIG. 1. First instar *B. fluminea.*

FIG. 2. Second instar, *B. fluminea.*

FIG. 3. Third instar, *B. fluminea.*

FIG. 4. Fourth instar, *B. fluminea.*

FIG. 5. Egg of *B. fluminea.*

FIG. 6. Egg hatching. Note the red eye spots appearing. The thin margins of the nymph are rolled ventrally.

FIG. 7. Fifth instar *B. fluminea.*

FIG. 8. Front tarsus of first instar of *B. fluminea.* Note the size of the claws. Compare with figure 9.

FIG. 9. Front tarsus of second instar of *B. fluminea.* The second claw diminishes in size till in the adult it is not present.

FIG. 10. Antenna of first instar nymph *B. fluminea.*

FIG. 11. Antenna of fifth instar nymph *B. fluminea.*

FIG. 12. Ventral view of abdomen of female *B. fluminea.*

FIG. 13. Egg of *Lethocerus Uhleri* laid in laboratory.

FIG. 14. Ventral view of abdomen of male *B. fluminea.*

FIG. 15. Ventral abdominal view of *Benacus griseus,* female.

FIG. 16. Single eggs of *Benacus.*

FIG. 17. Ventral abdominal view of *Benacus griseus,* male.

PLATE XVII.

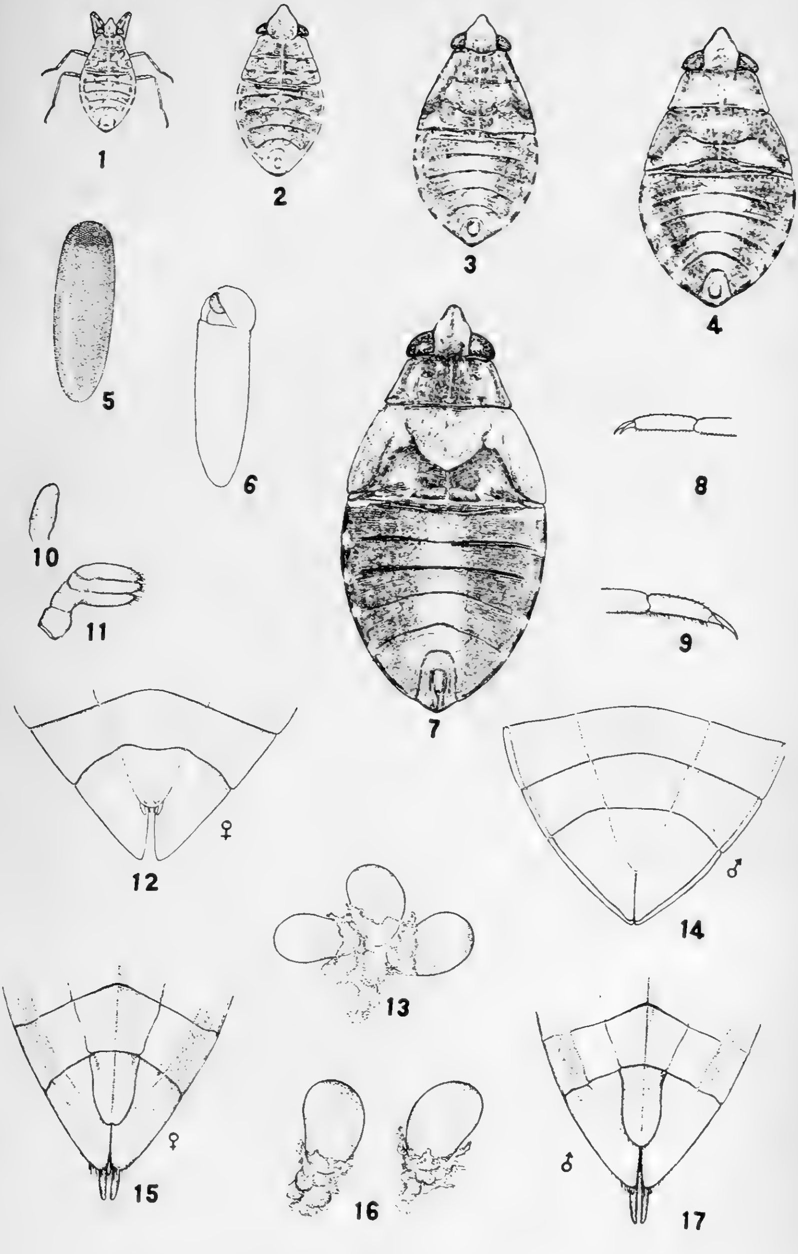


PLATE XVIII.

RANATRA AND NEPA.

FIG. 1. Ventral view of the tip of abdomen of female *Ranatra.* Note the narrow carinated ventral plate.

FIG. 2. Ventral view of tip of abdomen of male *Ranatra.* Note broad ventral plate.

FIG. 3. Enlarged egg of *Ranatra.* Note micropylar area near the base of the filaments.

FIG 4. Ventral view of head and prothorax of *Ranatra* to show tonal device. (See, also, figure 9.) The inner margin of the prothoracic shoulders (*b*) is roughened by a series of tiny ridges over which a roughened patch (*a*) on the outside of the coxa rubs.

FIG. 5. Fore leg of *Ranatra.*

FIG. 6. The cephalic end of a *Ranatra* egg, showing the post-natal molt and the rent in the egg shell through which the nymph emerged.

FIG. 7. Fore leg of Nepa.

FIG. 8. Cephalic end of *Ranatra* egg, side view. Note the micropyle (*m*).

FIG. 9. Tonal device of *Ranatra,* (*c*) coxa outside view, with rougened patch (*a*). Shoulder of prothorax with rasp (*r*) along its inner margin. (See figure 4.)

FIG. 10. Hydrachnid larva attached to caudal filament of *Ranatra,* thus making the tube nonfunctional to this point.

FIG. 11. Ventral view of abdominal tip of female Nepa.

FIG. 12. Egg of *Nepa apiculata.* Note that there are eleven filaments in our species. The European form has long been described as possessing seven.

FIG. 13. Ventral view of abdominal tip of male Nepa. Compare with figure 11.

PLATE XVIII.

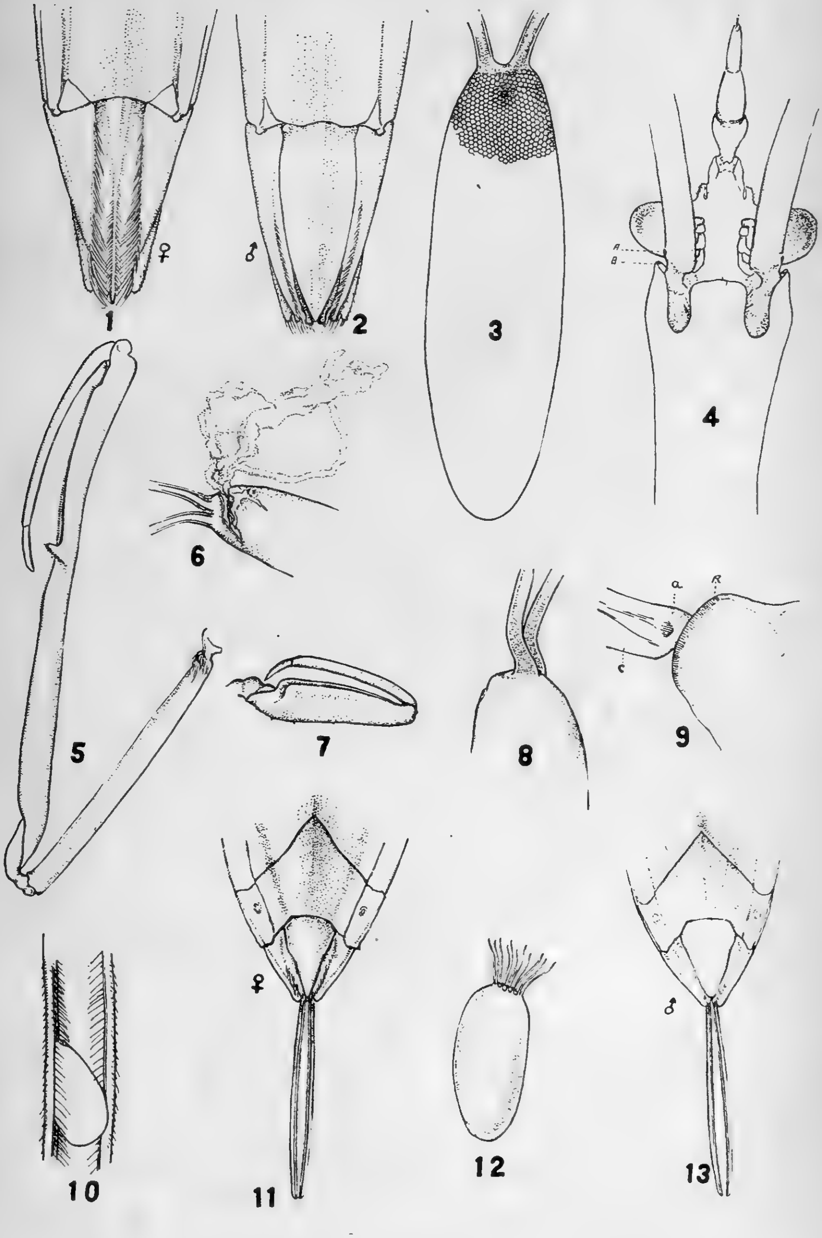


PLATE XIX.

NOTONECTA NYMPHS.

FIG. 1. Dorsal view of *Notonecta variabilis* first instar nymph.

FIG. 2. Dorsal view of *Notonecta irrorata* first instar nymph.

FIG. 3. Dorsal view of *Notonecta insulata* first instar nymph.

FIG. 4. Egg of *N. insulata.*

FIG. 5. Hind femur of first instar nymph of *Notonecta variabilis.*

FIG. 6. Egg of *N. irrorata.*

FIG. 7. Hind femur of first instar nymph of *Notonecta insulata.* Compare with figure 5.

FIG. 8. Egg of *N. variabilis.*

FIG. 9. Middle femur (ventral view) of *N. irrorata* first instar nymph.

FIG. 10. Egg of *N. undulata.* Figures 4, 6, 8 and 10 to same scale.

FIG. 11. Middle femur (ventral view) of *N. variabilis.* Compare with figure 9.

FIG. 12. Eggs of *Buenoa margaritacea* inserted in stem.

FIG. 13. Hind leg of first instar nymph of *N. variabilis.* Note the banded leg.

PLATE XIX.

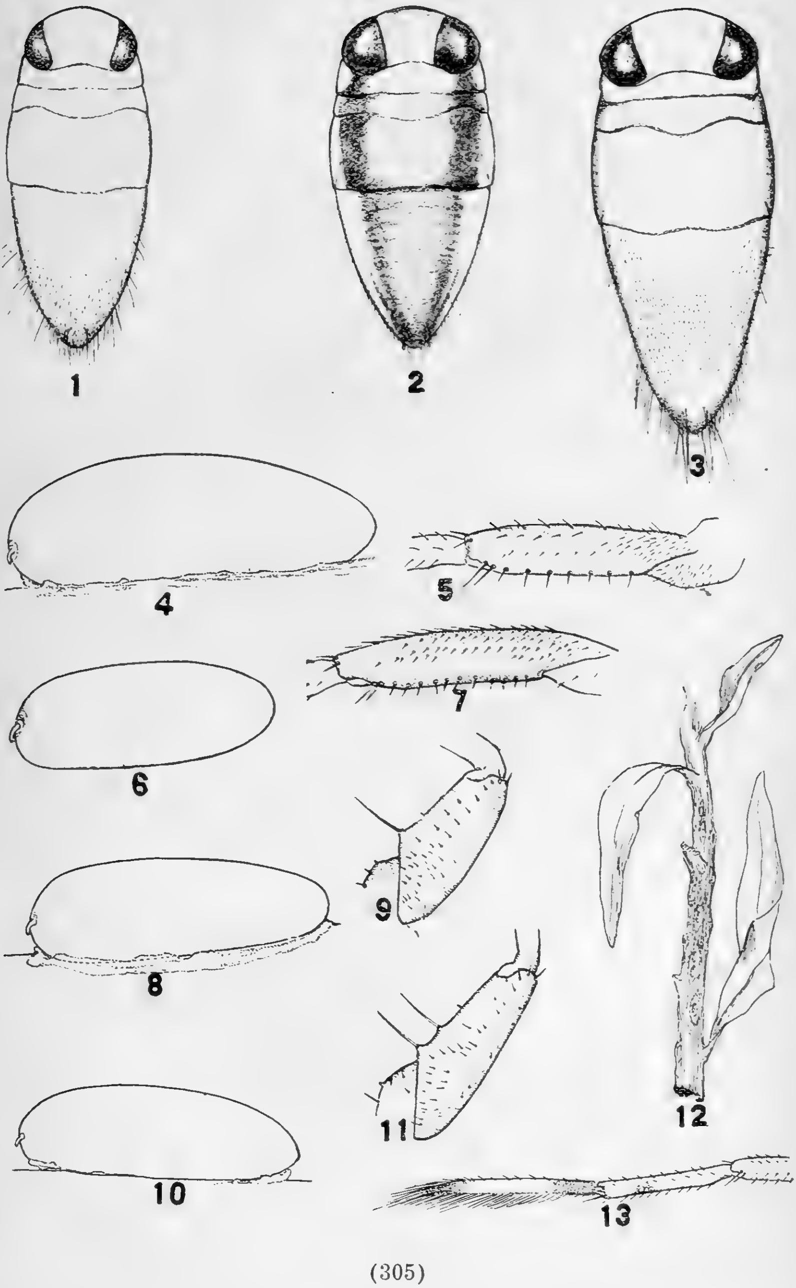


PLATE XX.

FIG. 1. Ventral view of terminal abdominal segments of male *Notonecta undulata* Say.

FIG. 2. Fifth instar nymph.

FIG. 3. Ventral view of terminal abdominal segments of female.

FIGS. 4*a* to 4*e*. Diagrams of dorsal view of meso- and metathorax of nymphs, first to fifth instars, respectively, showing the developing wing-pads.

FIG. 5. Third instar nymph. Both rows of swimming hairs shown.

FIG. 6. Antennæ of fifth instar nymph.

FIG. 7. Antennæ of adult male.

FIG. 8. Second instar feeding upon an ostracod.

FIG. 9. First instar nymph, drawn by Miss Ellen Edmonson.

FIG. 10. Tarsus of hind leg of first instar nymph, showing the tarsal claws, which become less conspicuous as development advances.

FIG. 11. Egg of *Notonecta undulata,* showing details of structure, drawn by Miss Ellen Edmonson. Plate first used in Ento. News, XXVIII.

PLATE XX.

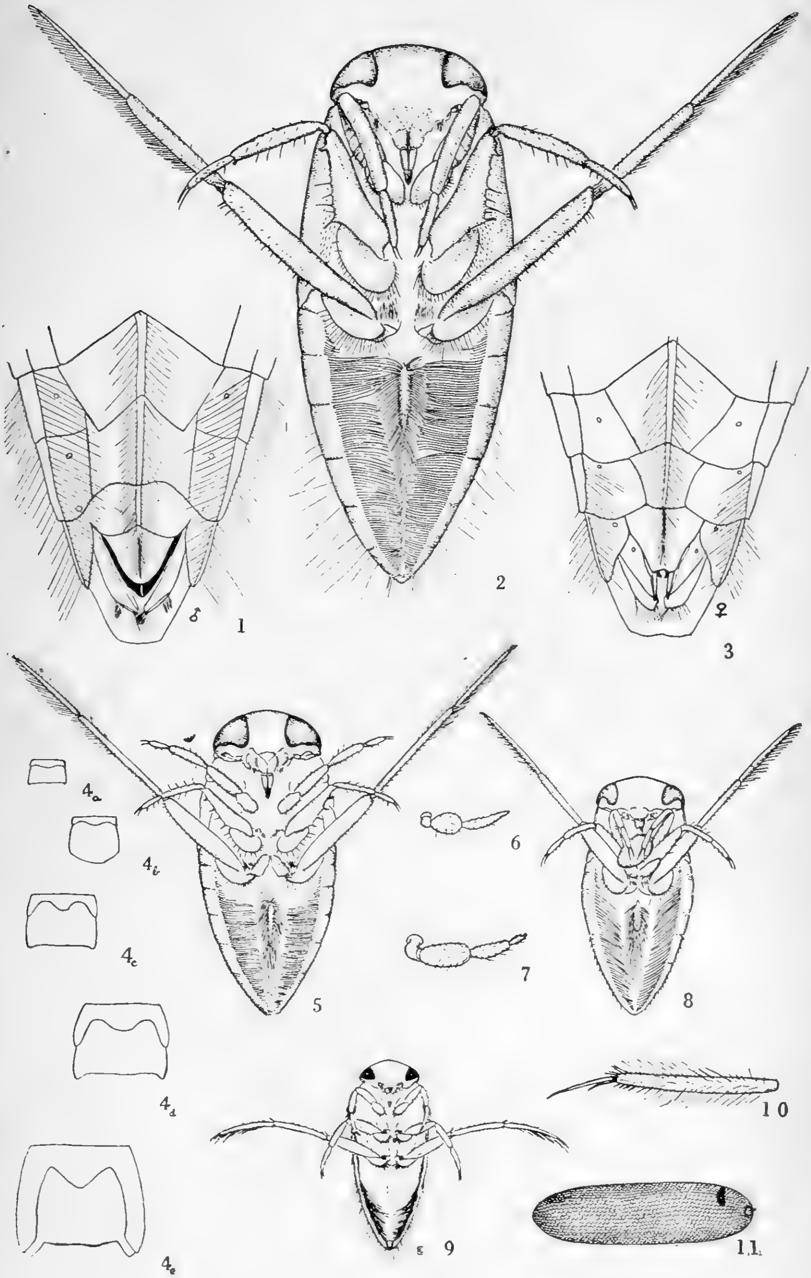


PLATE XXI.

FIG. 1. Two eggs of *Notonecta undulata* after hatching, showing the characteristic slit in the shell and the clear embryonic membrance shed by the nymph upon emerging.

FIG. 2. Adult *Notonecta undulata* in the water.

FIG. 3. Egg nearly ready to hatch. Note the red eye spot and the dark line at margin of the gelatinous substance which glues the egg to its support.

FIG. 4. A freshly laid egg viewed from above.

FIG. 5. A roadside pool in early spring. The back-swimmers were arriving in numbers, flying from some unknown quarters where they had passed the winter.

FIG. 6. Eggs of *Notonecta undulata,* freshly laid upon old weed stems lodged in the waters of the pool. *Gyrinid* beetles lay somewhat similar eggs, which may be distinguished by their arrangement upon their support and by the fact that the eye spots in advanced eggs are black instead of red, and farther from the end of the egg than in those of the back-swimmers. Plate first used in Ento. News, XXVIII.

PLATE XXI.

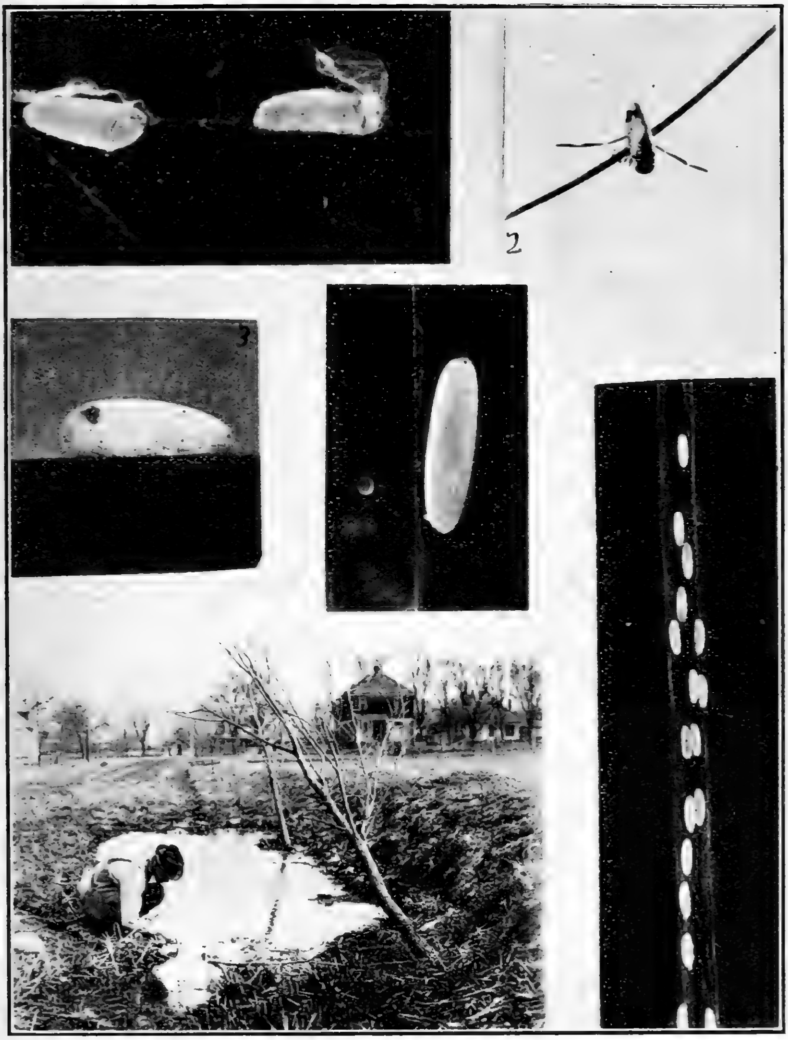


PLATE XXII.

NOTONECTA IRRORATA.

FIG. 1. Ventral view of the genitalia of the female *N. irrorata,* showing the drilling parts of the ovipositor, indicated by V. It is one of these parts that is figured from three aspects in plate XXIII, figure 9.

FIG. 2. A portion of water-soaked cattail leaf showing two eggs of *N. irrorata* deposited through one puncture.

FIG. 3. Egg of *N. irrorata* in moneywort stem. The embryos usually develop with cephalic end at micropylar pole of the egg. This one is reversed, as shown by the eye spot of the developing nymph within.

FIG 4. Egg in moneywort, showing the nature of the rent through which the nymph escaped. Postnatal molt removed.

FIG. 5. Ventral view of the genitalia of the female *N. insulata,* showing the drilling parts of the ovipositor, indicated by V. It is one of these parts that is figured from three aspects in plate XXIII, figure 5. This plate appeared in Ento. News, XXIV.

PLATE XXII.

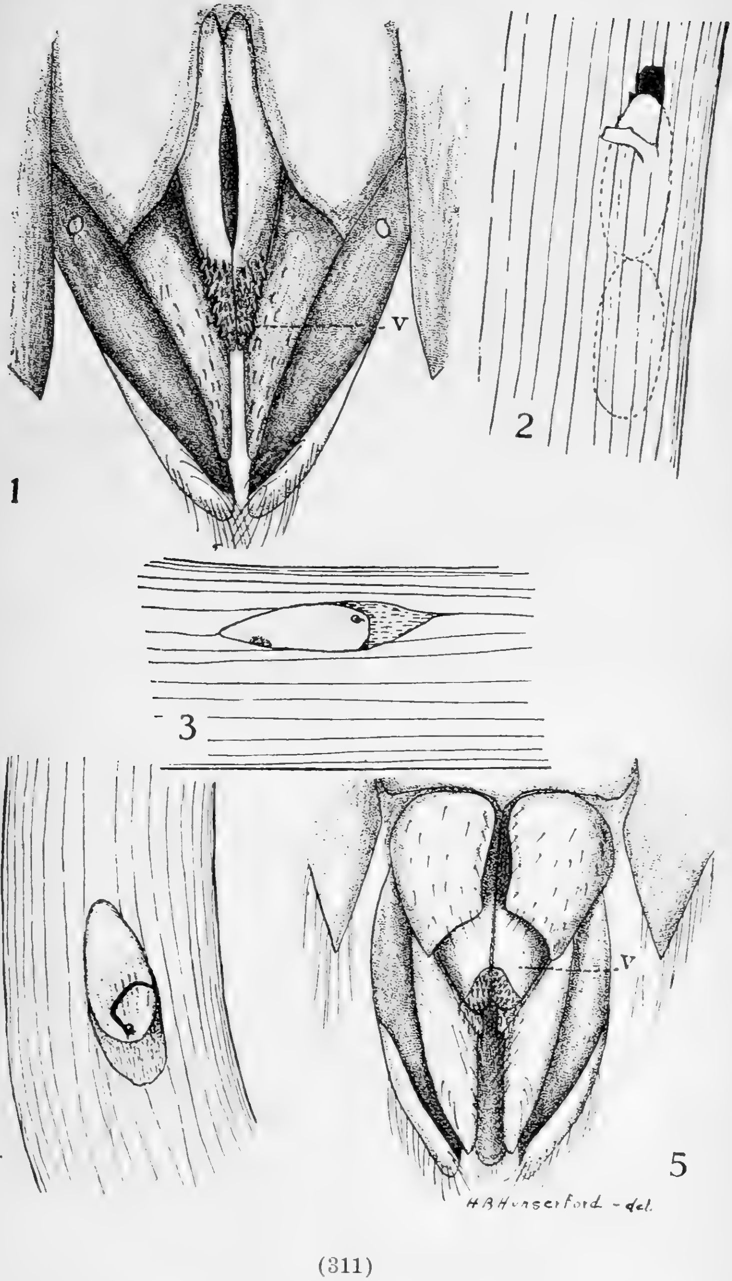


PLATE XXIII.

OVIPOSITOR OF NOTONECTÆ.

This plate contains three views of the left member of the first pair of gonapophyses of the female of each of the species of the genus Notonecta available in this country. Two species have been omitted because of the lack of material.

The views are from left to right, outside or lateral view; ventral view showing the organ on edge, inner view. All of the drawings were made with camera lucida and drawn to the same scale. The length of the adult, together with outside measurements of the ovipositor, are added for purposes of comparison of relative size of parts. The writer believes that a study of these organs should be taken into account in determining relationship of species. A study of a wide series would certainly establish the range of variability in size and shape of these parts, and in some cases, if not all, aid in specific determinations. The drawings here presented are, however, intended to indicate merely the correlation of this organ with the habit of oviposition.

FIG. 1. *Notonecta lutea.* Size of adult, 13-17.1 mm.; valve of ovipositor, 1.625 mm. x .725 mm. Specimen loaned by Mr. Gibson, of Nat. Mus. Taken in Finland by Sahlberg and determined by Kirkaldy.

FIG. 2. *Notonecta raleighii.* Size of adult, 9 mm.; valve of ovipositor, .4 mm. x .25 mm. Specimen given to me by Mr. J. R. de la Torre Bueno.

FIG. 3. *Notonecta undulata.* Size of adult, 10-13 mm.; valve of ovipositor, .5 mm. x .312 mm. Material from Ithaca, N. Y., and Lawrence, Kan.

FIG. 4. *Notonecta variabilis.* Size of adult, 8.2-10.2 mm.; valve of ovipositor, .4 x .312 mm.

FIG. 5. *Notonecta insulata.* Size of adult, 12.6-15.5 mm.; valve of ovipositor, .7 x .425 mm. Material from Palo Alto, Cal.

FIG. 6. *Notonecta glauca.* Size of adult, ?; valve of ovipositor, 1.125 x .55 mm. Loaned from Nat. Museum by Mr. Gibson; a specimen from England, collected by Uhler.

FIG. 7. *Notonecta Mexicana.* Size of adult, 11-14 mm.; valve of ovipositor, .7 x .5 mm. Specimens from Arizona.

FIG 8. *Notonecta shooterii.* Size of adult, 8-13 mm.; valve of ovipositor, .65 x .375 mm. Specimen given to me by Mr. J. R. de la Torre Bueno.

FIG. 9. *Notonecta irrorata.* Size of adult, 11.8-14.4 mm.; valve of ovipositor, 1.675 x .575 mm. Material taken at Ithaca, N. Y.

FIG. 10. *Notonecta uhleri.* Size of adult, 12 mm.; valve of ovipositor, .65 x .35 mm. Specimen given to me by Mr. de la Torre Bueno.

FIG. 11. *Notonecta indica.* Size of adult, 10.5 mm.; valve of ovipositor, .5 x .375 mm. Material from Douglas, Ariz., collected by Doctor Snow. Plate first used in Ento. News, XXVI.

PLATE XXIII.

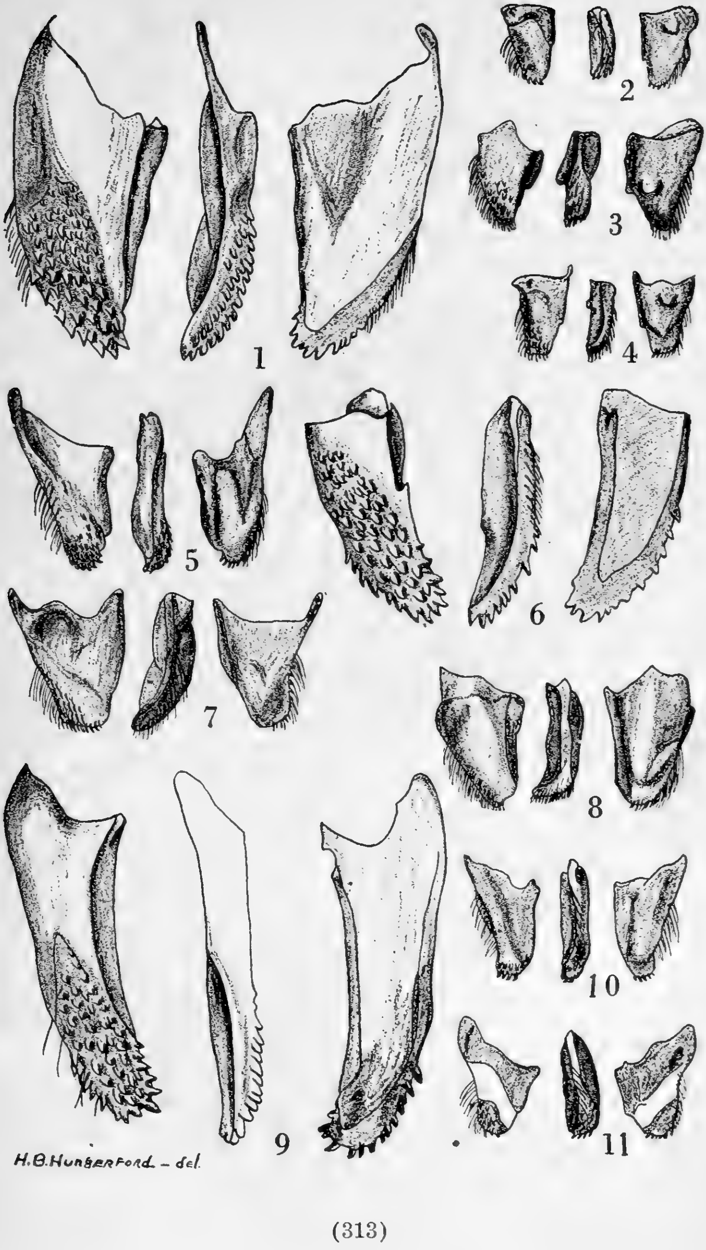


PLATE XXIV.

BUENOA MARGARITACEA.

All the figures refer to *Buenoa margaritacea* unless otherwise stated.

FIG. 1. Egg removed from the stem, showing the clear exposed area of the egg and its margin of white.

FIG. 2. Eggs "in situ" in stem of *Juncus*.

FIG. 3. A portion of the stem of *Juncus* removed to the egg in situ.

FIG. 4. Ventral view of the female, showing the appearance of the ovipositor and the crib formed by the two anterior pairs of legs for the retention of entomostracans. Compare with figure 10.

FIG. 5. Inner view of the stridular areas on the femur and tibia of the anterior leg of the male, greatly enlarged from figure 6.

FIG. 6. Inner view of the anterior leg of male, showing the tibial prominence and stridular areas.

FIG. 7. Eggs of *Notonecta undulata* glued to the stem of aquatic plant. Drawn from a photograph. Plate from Ento. News, XXVIII.

PLATE XXIV.

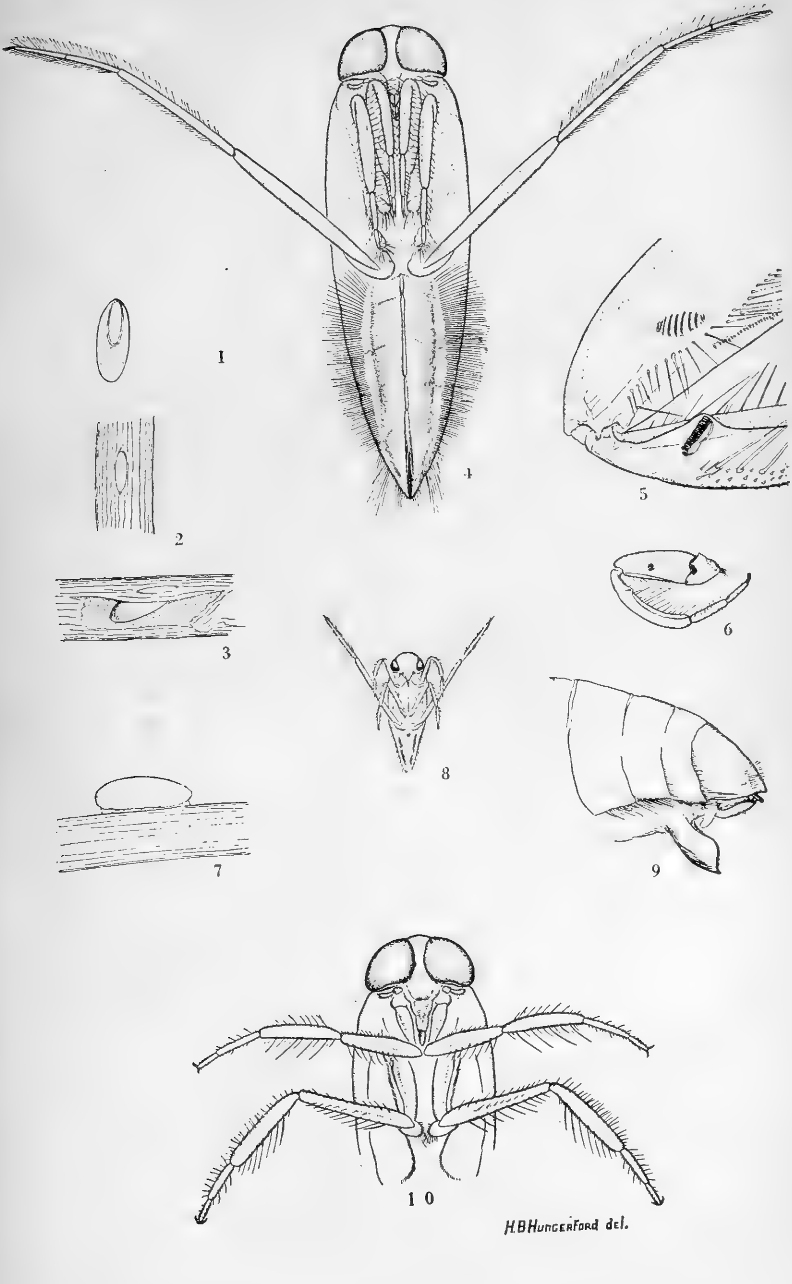


PLATE XXV.

PLEA STRIOLA.

FIG. 1. A sprig of water weed (*Elodea*) with the inserted eggs of *Plea*. An adult drawn to same scale as eggs shown.

FIG. 2. Adult female *Plea*, with her ovipositor exserted.

FIG. 3. Egg of *Plea*, same scale as figure 2.

FIG. 4. Side view of body of *Plea*, hemelytra removed showing the wing-pad. Some have the flying wings much better developed than this specimen.

FIG. 5. Egg of *Plea* inserted in plant tissue.

FIG. 6. Egg of *Plea*.

FIG. 7. Ventral view of male abdomen of *Plea*.

FIG. 8. The edge of the right hemelytron shown in figure 9. Note the white ridge with its irregularities that snap into irregularities of the open hemelytron, making a firm union of the two. This has led writers to state that the hemelytra of our *Plea* are soldered into one piece.

FIG. 9. Hemelytra of *Plea*, showing suture clasping device.

FIG. 10. Ventral view of female abdomen of *Plea striola*.

PLATE XXV.

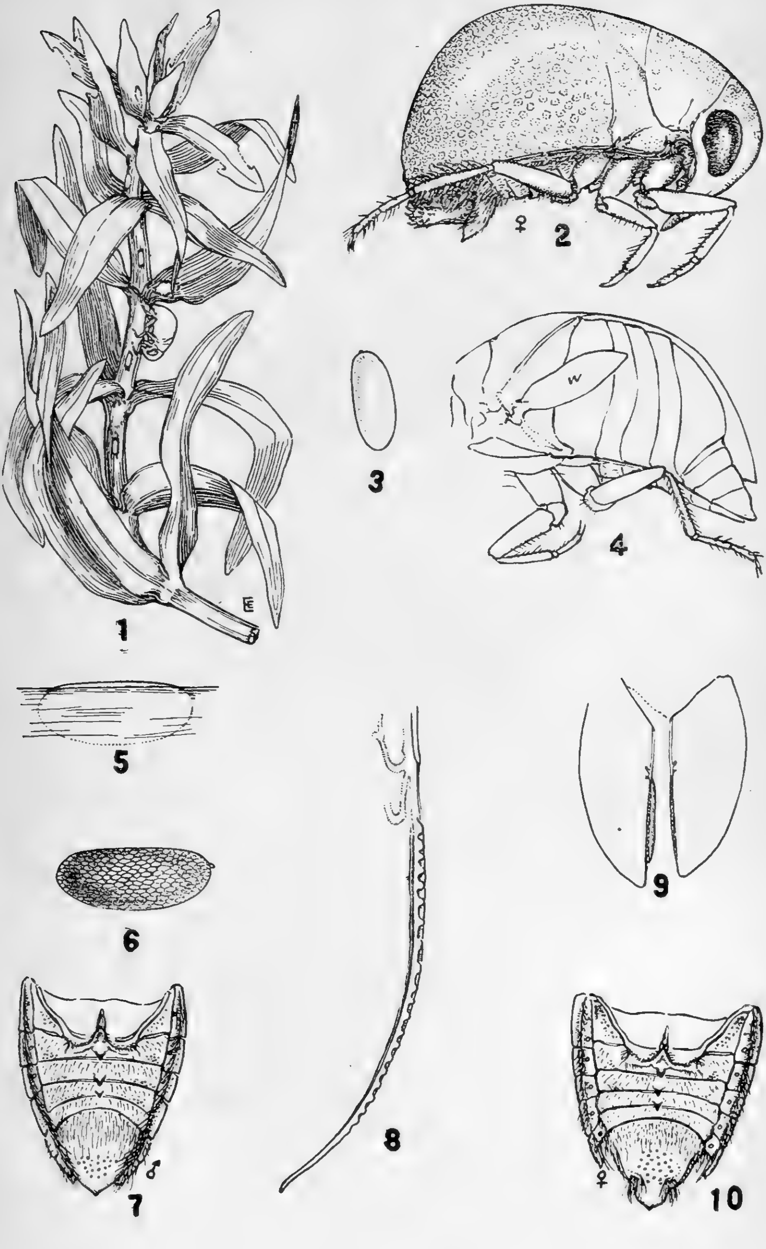


PLATE XXVI.

ARCTOCORIXA ALTERNATA.—Kansas Material.

FIG. 1. Egg of the Corixid species here considered.

FIG. 2. Adult Corixid, *Arctocorixa alternata.*

FIG 3. Egg of a smaller species.

FIG. 4. First instar nymph.

FIG. 5. Second instar nymph.

FIG. 6. Tarsus and claws of hind leg of first instar.

FIG. 7. Third instar. Note the fringe of black hairs on the wing-pads.

FIG. 8. Egg shell after hatching, showing the characteristic rupturing of the egg for the egress of the nymph.

FIG. 9. Fourth instar nymph.

FIG. 10. Front leg of late fifth instar nymph, showing the tibia and tarsus of the adult within the terminal nymphal segment.

FIG. 11. Fifth instar nymph.

FIG. 12. The foreleg of the adult male.

FIG 13. Ventral view of abdomen of female.

FIG. 14. Antenna of third instar nymph.

FIG. 15. Antenna of late fifth instar, showing the three distal segments of the adult in the terminal nymphal segment.

FIG. 16. Antenna of adult.

FIG. 17. Ventral view of abdomen of male, showing the peculiar arctoco asymmetry of the segments. Plate appeared in Jr. N. Y. Ento. Soc., XXV.

PLATE XXVI.

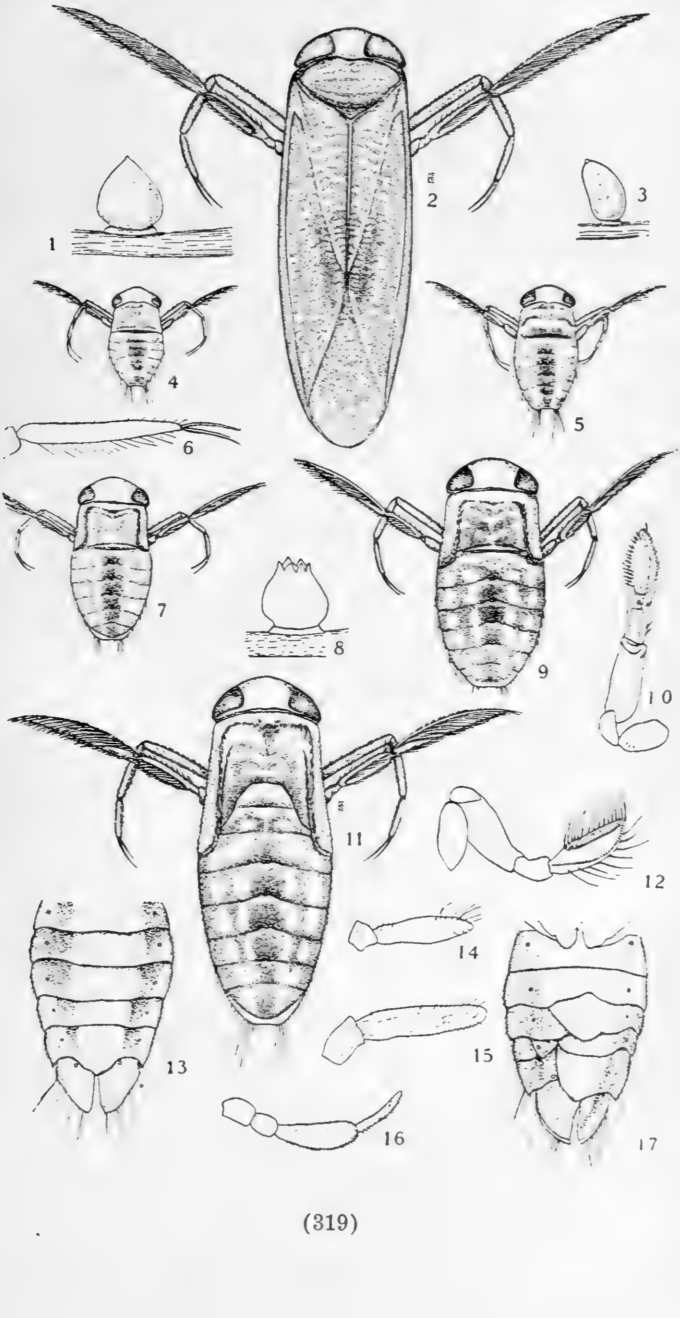


PLATE XXVII.

FIG. 1. Fifth instar of *Palmacorixa buenoi.*

FIG. 2. Male *Palmacorixa buenoi* from Beebe lake.

FIG. 3. Male *Palmacorixa buenoi* from Bool's Backwater, nearby. These sizes are distinct.

FIG. 4. Fourth instar nymph of *Palmacorixa buenoi.*

FIG. 5. Third instar nymph of *Palmacorixa buenoi.*

FIG. 6. Second instar nymph of *Palmacorixa buenoi.*

FIG. 7. First instar nymph of *Palmacorixa buenoi.*

FIG. 8. First instar nymph of *Arctocorixa alternata.* N. Y. variety.

FIG. 9. Fourth instar nymph of *Arctocorixa alternata.* N. Y. variety.

FIG. 10. Third instar nymph of *Arctocorixa alternata.* N. Y. variety.

FIG. 11. Second instar nymph of *Arctocorixa alternata.* N. Y. variety.

FIG. 12. Fifth instar nymph of *Arctocorixa alternata.* N. Y. variety,

Compare the various instars of the two bugs as to color pattern.

PLATE XXVII.

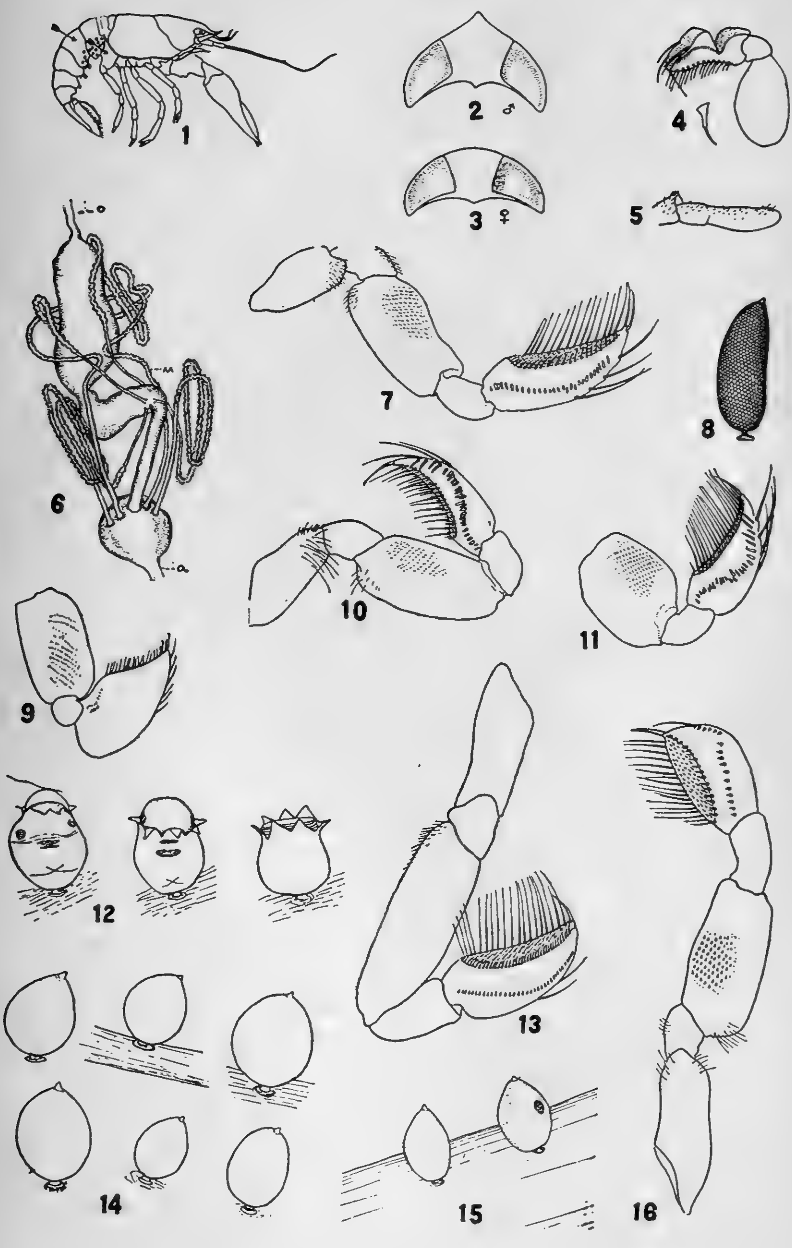


PLATE XXVIII.

CORIXIDÆ.

FIG. 1. Crayfish bearing eggs of the Corixid *Ramphocorixa acuminata.* The arrows show the direction of the water current. The writer believes this accounts for the presence of the first eggs of the *Corixid* on the first abdominal pleurites.

FIG. 2. Head of male of *Ramphocorixa acuminata* from above.

FIG. 3. Head of female of *R. acuminata.*

FIG. 4. Pala of male of *R. acuminata.*

FIG. 5. Antenna of 5th instar nymph of *R. acuminata.*

FIG. 6. Digestive system of a *Corixid* to show the termination of the malpighian tubules against the rectal pouch.

FIG. 7. Front leg of male *Palmacorixa buenoa* found in Beebe lake. It is a much larger bug than is found in Bool's Backwater, nearby. See plate XXIV.

FIG. 8. Egg of *Ramphocorixa acuminata.*

FIG. 9. Front leg of male *Palmacorixa gillettei.* Abbott. Copied from Abbott.

FIG. 10. Front leg of *Palmacorixa buenoi.* Abbott, from Bool's Backwater.

FIG. 11. Same as figure 10. Note the variation.

FIG. 12. The hatching of a *Corixid.* First a bubble appears after the egg bursts, then the nymph slowly fills the bubble. This postnatal molt bursts when the nymph is two-thirds way out. It remains as a cast and crumpled garment as shown.

FIG. 13. Male pala of *Corixid.*

FIG. 14. Eggs of various species of *Corixids.*

FIG. 15. *Corixid* egg. Showing how the egg enlarges as embryo develops within.

PLATE XXVIII.

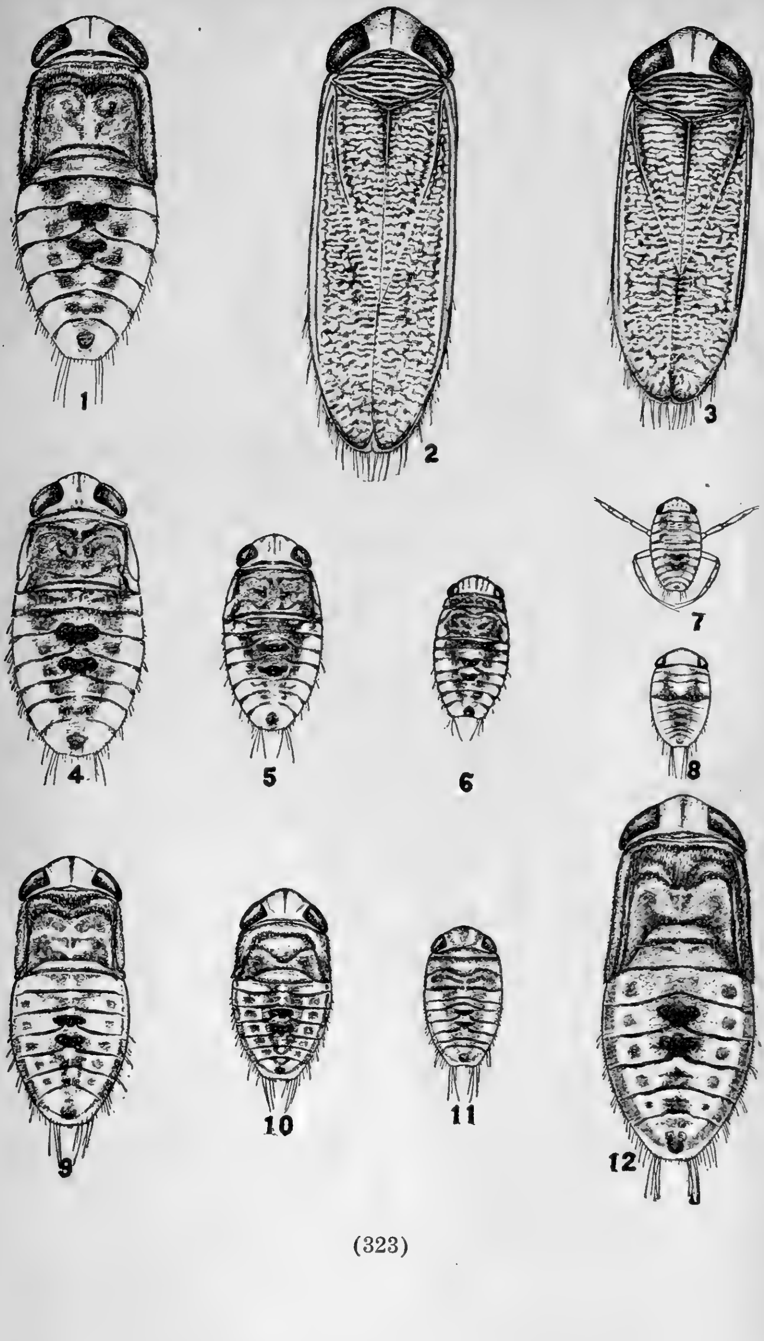


PLATE XXIX.

FIG. 1. Cephalic view of head and forelegs of a female *Corixid.* The left leg has been turned in a position to show the nature of the paler surface, which in the right leg is appressed to the face.

FIG. 2. The extremity of the beak of a *Corixid* from a specimen cleared in caustic potash. It shows two of the stylets and the nature of their tips. It also reveals the fact that they are strongly chitinized only for a short distance. They afford a remarkable contrast to the stylets of Hydrometra, which are exceedingly long and capable of being exserted beyond the tip of the beak a distance nearly as great as the length of the beak itself.

FIG. 3. The tip of a stylet of Hydrometra to show its equipment for retaining prey. These stylets when not exserted extend well back into the peculiarly long head of the bug. Hydrometra spears its prey, and depends upon the effectiveness of its barbed stylets to hold, and its poisonous salivary injections to subdue, the victim.

FIG. 4. A view of the pala of the right foreleg of a female boatman. An efficient device for scooping up and bringing to the mouth the sedimentary material in the deposits on the bottom of the pool.

FIG. 5. Lateral view of the head and forelegs of a male *Corixid,* to illustrate the process of food gathering. The arrows indicate the direction of the food material. The stylets are shown exserted, one foreleg passing food material across the face and over the buccal opening, the other in the act of gathering material.

FIG. 6. The right foreleg of a *Naucorid* seen in ventral view. This presents the usual modification of the foreleg for grasping, and is shown in contrast to the type of the foreleg of the boatmen, so long believed to be predaceous. Plate used in Jr. N. Y. Ento. Soc. XXV.

PLATE XXIX.

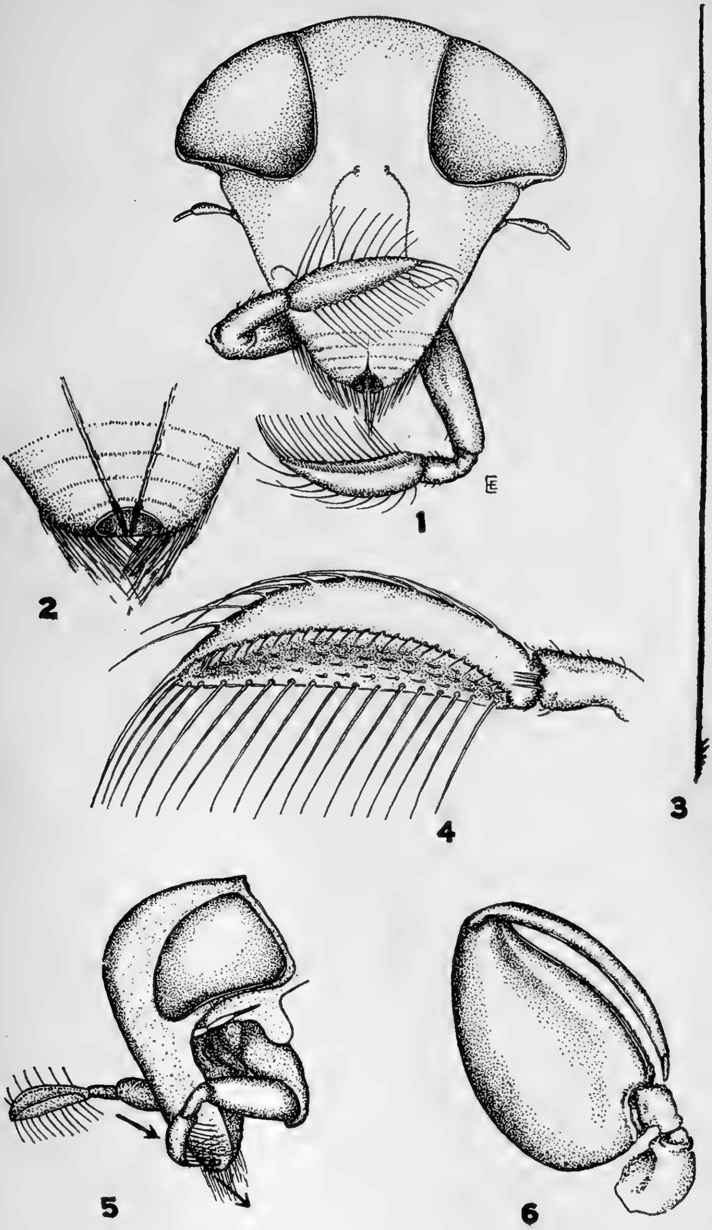


PLATE XXX.

CORIXID MOUTH PARTS AND DIGESTIVE TRACT.

FIG. 1. The digestive tract of a *Corixid*, showing the long green filament of algæ which it had eaten. Sometimes the boatmen fill their stomachs with great skeins of Oscillatoria. (The above drawing was made from a permanent slide, the green color being preserved by fixation in 8% formalin plus copper acetate.)

FIG. 2. The tip of the so-called rostrum of a large species of *Corixid*. The median stylets and one lateral stylet (in black) are shown projecting from the small oral opening (o). This opening is bounded by the membrane (m), which is provided with the chitenous trusses (I). These trusses are attached to the muscles (mu). Thus when the muscles contract the oral opening is considerably enlarged.

Note the projecting, somewhat spoon-shaped guards, below (g). When the palæ of forelegs sweep downward across the face these concave shields help to keep the food from passing beyond its objective.

FIG. 3. Digestive system of a *Corixid*. The inner surface is increased by diameter instead of by length. There are four malpighian tubules. This drawing is from the mount of the digestive tract of a bug that had fed for a few minutes over some sediment lightly sprinkled with carmine grains. Quantities of carmine were swept in with the organic ooze.

FIG. 4. Ventral enlarged view of mouth parts dissected. The mandibular stylets are on the outside.

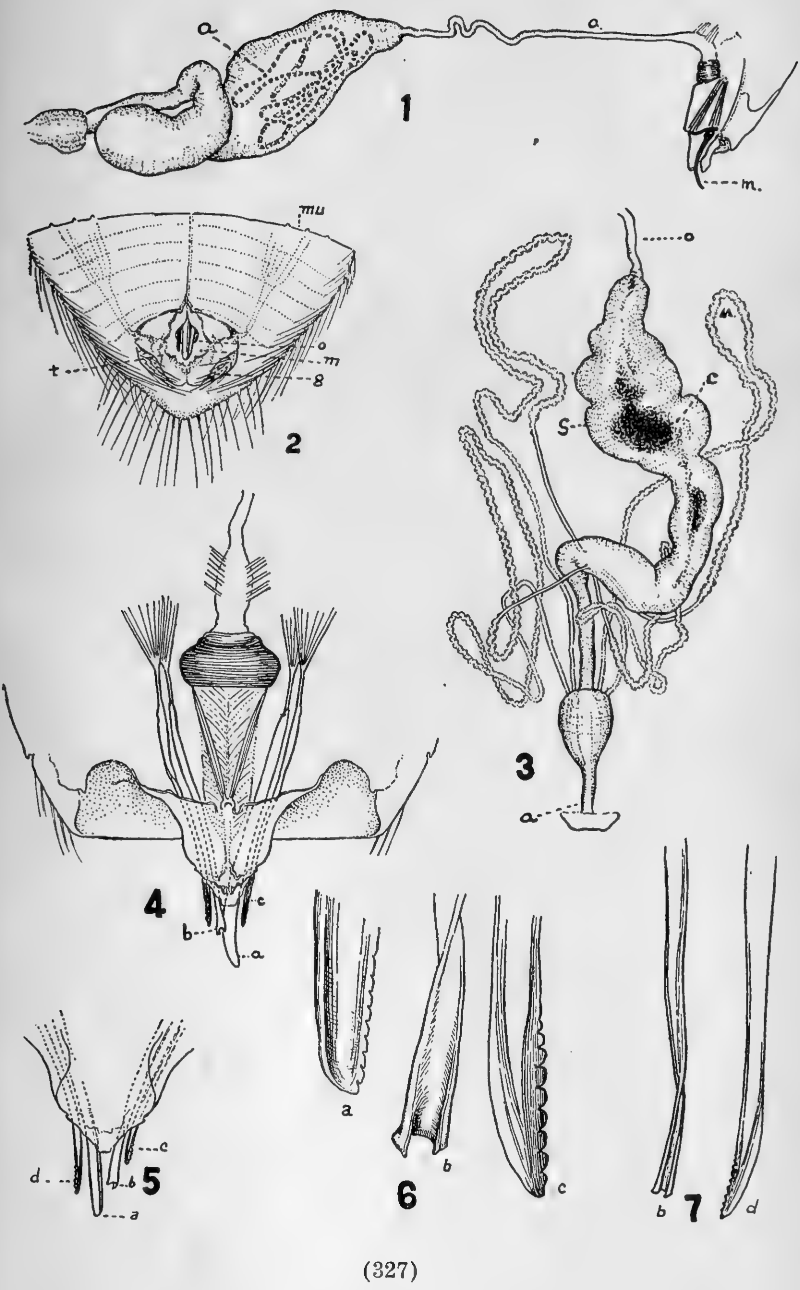
FIG. 5. Dorsal or cephalic view of mouth parts.

FIG. 6. Stylets enlarged.

a. right inner stylet.
b. left inner stylet.
c. left outer stylet. (See, also, figure 5.)

FIG. 7. Shows left inner or maxillary stylet (*b*) and right outer or mandibular stylet.

PLATE XXX.



ERRATA.

The color plates are the work of the Bureau of Engraving, Inc., Minneapolis, Minn. For some reason their mark was omitted from the face of the plates.

Color plate II was not reduced as ordered, therefore the magnifications are incorrect.

Fig. 1.	Magnification 4.5	instead of	3.50
Fig. 2.	Magnification 5.0	instead of	3.90
Fig. 3.	Magnification .9	instead of	.70
Fig. 4.	Magnification 4.5	instead of	3.50
Fig. 5.	Magnification .9	instead of	.70
Fig. 6.	Magnification .9	instead of	.70
Fig. 7.	Magnification 2.1	instead of	1.66
Fig. 8.	Magnification 2.8	instead of	2.20
Fig. 9.	Magnification 1.8	instead of	1.40

The Male Genitalia as Characters of Specific Value in Certain Cryptocerata (Hemiptera-Heteroptera).

The use of the male genitalia in specific determination has been employed for a long time in certain groups of insects. For the most part their use has been limited to those forms possessing readily accessible and perfectly apparent genital parts.

It has been demonstrated in recent years, by Doctor Knight in the Miridæ and Crawford in the Homoptera, that a close scrutiny of the male genitalia of forms superficially difficult to separate affords a solution to hitherto perplexing problems.

The writer published a study of the "Oviposition of the Notonectæ" in the *Entomological News,* vol. XXIX, 1918. This was in no way a systematic paper and had in mind the relation of form to function only. It was stated, however, that the gonapophyses appeared to be specifically distinct in size and shape and the suggestion was made that a study of the males might be worth while.

It was the writer's good fortune to be carrying on research work in the same quarters in which Dr. Harry Knight was working over his Miridæ. It was upon his advice that the writer undertook to discover specific characters in certain of the water bugs. This undertaking was in the face of some discouragements, for Kirkaldy wrote: "Great hopes were entertained by me that the male genitalia (of Notonecta) would furnish a reliable diagnostic character, but in the few species (*N. glauca, N. lutea, N. irrorata,* and *N. undulata*) of which suitable material was available, these hopes have not been realized." Furthermore, Mr. J. R. de la Torre Bueno admitted, when the problem was suggested to him, that he had long had in mind such a study but that the species in the genus *Notonecta* are most confusing.

The writer, however, had before him the necessity of solving some questions of specific determination that had arisen in connection with his biological work in the Corixidæ. From these researches came his determination to master the tax-

onomy of this family and to prepare a monograph of it, a work in which he has been engaged for some time.

A searching examination of some of the related families has shown some of them to possess quite specifically distinct genital characters. The males of Gelastocoridæ, Notonectidæ and Corixidæ have the genital claspers attached to a capsule-like segment which is capable of being withdrawn into the body and thus lies hidden. This strongly chitinized capsule is but loosely attached to the body wall and can therefore be drawn forth and removed from the bug *in toto* without the least injury or mutilation to the external features of the specimen.

For these studies the specimen was first relaxed, then held under the binocular while the genital capsule was removed, an operation requiring considerable skill in some Corixidæ. The capsule was then placed in a vial of caustic potash and left until sufficiently clear for study.

The drawings submitted herewith were made with a camera-lucida and all drawn to the same scale. The suranal plate and intromittent organ have been omitted in the drawings for sake of clearness. This paper is preliminary in nature and intended only to call attention to the possibility of using the genitalia of the males of some of the aquatic and semi-aquatic Hemiptera, a line of characters not hitherto used, in their taxonomy. The genitalia of the Belostomatidæ and Nepidæ are not used in these studies because these families are under investigation by others. The genitalia of Corixidæ are not figured, for the reason that a completed study of the family by the writer will appear later.

The genital segment bearing the male claspers in the Saldid is exposed and the removal of more than the claspers themselves would mutilate the specimen. The Naurcorids examined carry a relatively smaller capsule with claspers that, while different in shape in the two or three species studied, are not so strikingly distinct as in some of the other forms. Of the three families having the genital capsule entirely hidden, the Notonectidæ have the simplest device. The capsule of a member of the genus *Notonecta* is erect and bilaterally symmetrical. The claspers, right and left, are about alike. The shape of the capsule itself as well as that of the claspers afford characters of specific value—as is shown by a study of

the drawings on plate XXXI. In the genus Buenoa we find the beginnings of asymmetrical development in that the right and left claspers are unlike. (A faint suggestion of this is to be found in *Pelocoris* and *Plea.*) See the drawings on plate XXXI, figures 1, 2 and 4.

In the families Gelastocoridæ and Corixidæ are found marked asymmetry, not only of the genital capsule and its parts, but of the abdominal segments themselves as well. The claspers of *Gelastocoris* are profoundly unlike—the ventral one (the right one) is large, stout, and equipped with short, blunt pegs or processes; the other one is small and not greatly modified in shape. See plate XXXII, figure 5, R. C. and L. C. The Corixid capsule and its parts are more complicated and perplexing than the forms above mentioned, but have been used by the writer with success as an aid to the separation of difficult species.

There are figured, herewith, the male genital segments of nine species in the genus *Notonecta**—two in *Buenoa,* one in *Plea,* two species of *Ambrysus,* two *Saldids,* and two *Gelastocorids.* The reading of the discussion which follows should be accompanied by an examination of plates XXXI and XXXII.

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* The figures of *Notonecta raleighi* Bueno, *Notonecta shooteri,* Uhl., *Notonecta uhleri* Kirk., *Notonecta montezuma* Kirk., and *Notonecta lutea* Mull. are not figured. *Notonecta lutea* from British Columbia, identified as such by Bueno, has a genital bulb much like *N. irrorata.* The ventral process is shorter and located farther cephalad. The fold of the lobe in front of the clasper extends to the ventral margin. These two species, *N. irrorata* and the so-called *lutea,* are quite related. The genital bulb of *Notonecta shooteri* resembles figure five very closely, and the bulb of *Notonecta raleighi* is very like that of *Notonecta variabilis.*

PLATE XXXI.

FIGS. 1 and 4. *Buenoa margaritacea, Bueno.* Left and right view of the male genital segment indicates the marked difference in the shape of the claspers. All the material in this genus examined shows a similar asymmetry. The bulb here figured was taken from a specimen identified by Mr. Bueno. L. C. = left clasper. R. C. = right clasper.

FIG. 2. *Buenoa elegans* (Fieb). The genital bulb of this species differs from its larger relative figured as above by the slight constriction as shown in the lateral profile of the lower margin. The left clasper has a larger basal lobe than the *Buenoa margaritacea* Bueno. The drawing is partly free hand, and the view is from the left side. The specimen from which this drawing was made was determined by Mr. Bueno. C. = clasper (left).

FIG. 3. *Plea striola* (Fieb.). This tiny back swimmer has a genital segment somewhat like its larger relatives. The drawing is made from the left side and shows the muscular base of the penis. The claspers are curved, the right one is slightly more slender and longer than the left—just a suggestion of asymmetry. This drawing is made from material taken in New York. A study of Kansas material shows a slight difference. Bueno has stated that he believes there is more than one species in the United States, and a careful study of the material of the country may prove his contention. The material in the Snow collections bears Bueno's label. C. = clasper (left).

FIG. 5. *Notonecta*—sp? The male genital bulb from a specimen that came to me among some Corixids. It lacks collector and locality label so it is not possible to say from whence it came. D. C. = dorsal collar. L. C. = left clasper.

FIG. 6. *Notonecta indica* Linn. The clasper is entire and the caudal margin of the capsule has not the same shape as that of *N. variabilis.* The clasper of *N. glauca* resembles it somewhat, but the capsule is very different in shape.

FIG. 7. *Notonecta irrorata* Uhl. The genital bulb of the male of this species is very different from the others in possessing a conspicuous fingerlike process on the ventral side. This is usually lighter in color than the rest of the bulb. Material examined from Ithaca, New York, and Wellington, Ohio.

FIG. 8. *Notonecta* sp. In this species the clasper is broad and massive and very shallowly bifurcate. From a study of some specimens collected by Chambliss at Knoxville, Tenn. These bugs in size and general appearance resemble *N. indica.* The scutellum lacks the lighter margin, however.

FIG. 9. *Notonecta insulata* (Kirby). Genital bulb from a male specimen taken in California. Note the singular shape of the capsule along its ventral line. In profile it makes almost a right angle. Material from California and New York examined.

FIG. 10. *Notonecta undulata* (Say). Genital bulb a little stouter than the majority of the others. The claspers strongly bifurcate, the caudal branch thick and blunt, the other long, curved somewhat mesally at tip. Material examined from Kansas, Missouri, and New York state.

Fig. 11. *Notonecta variabilis* (Fieb.). Genital bulb from a male specimen in the Snow collections at Kansas University bearing label of identification by Mr. J. R. de la Torre Bueno (specimen from Staten Island). Material also examined from Ithaca, N. Y. The rather slender clasper is bifurcate at tip; the caudal branch more slender than the other. The quite evenly rounded caudal margin of the capsule is also different from those nearest it in appearance. The ventral keel of the capsule is present and differs in shape from that of *N. undulata.*

FIG. 12. *Notonecta glauca.* The genital bulb or capsule from a male specimen given to me by Mr. J. R. de la Torre Bueno and bearing the locality label of Milano, Italy. The direction of the dorsal collar (D. C.) is directed backward somewhat instead of upwards as in most specimens. The clasper is entire and the bulb lacks the ventral keel possessed by *N. indica, N. undulata* and *N. variabilis.* The specimen was slightly damaged and the delineation may not be exactly true.

PLATE XXXI.

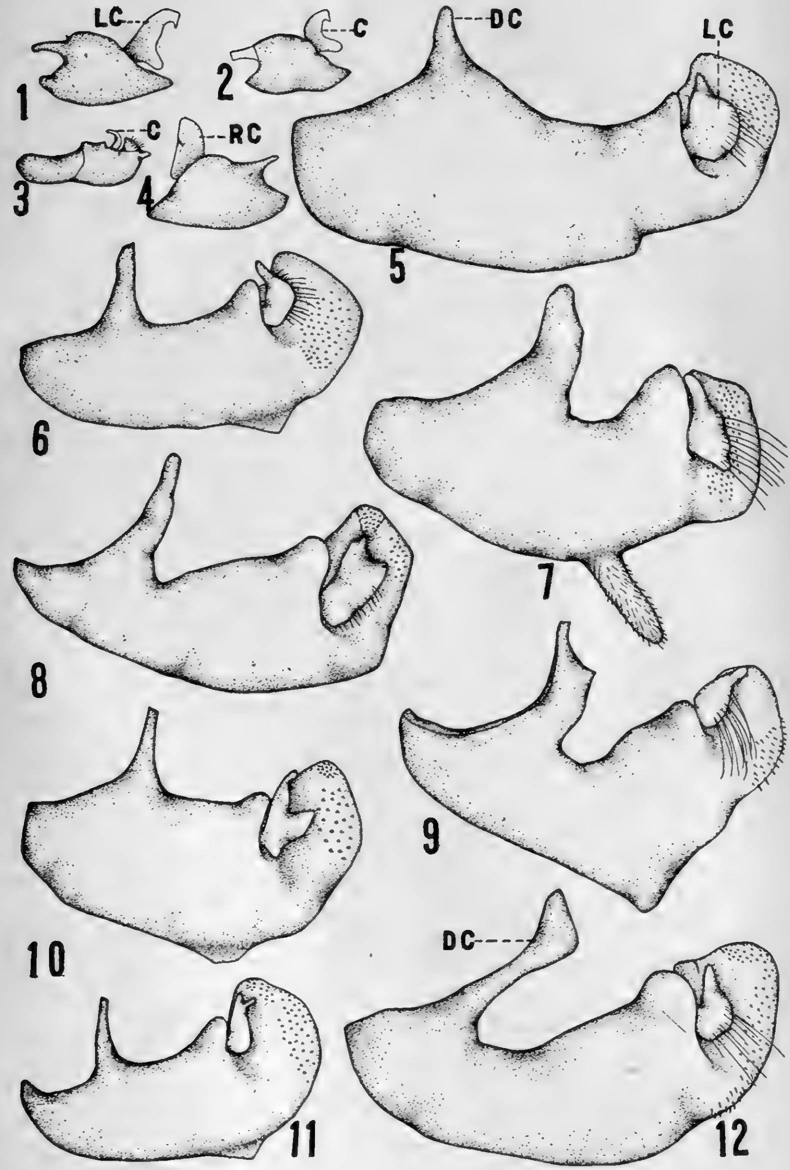


PLATE XXXII.

FIG. 1. *Ambrysus melanopterus* Stal. The genital segment from a specimen in the Snow collection determined by Van Duzee. The segment is more elongate than *A. signoreti* and the claspers more slender and truncate at tip. Another character in this group that may have possibilities is a chitinized flap that is present on the margin of one of latter abdominal tergites. Its position is on the right side in the material of the two species examined and distinctly different in shape.

FIG. 2. *Saldid.* The exposed genital segment of a species common in Kansas. Note the shape of the claspers and the tip of the genital segment as compared with *Pentacora signoreti* Guer., fig. 6.

FIG. 3. *Ambrysus signoreti* Stal. The genital segment from a specimen in the Snow collection determined by Van Duzee. The segment is plump and the claspers broad. The drawing is partly free hand and from dorsal view. This bug was taken by Doctor Snow at San Barnardino Ranch, Arizona (Cochise county).

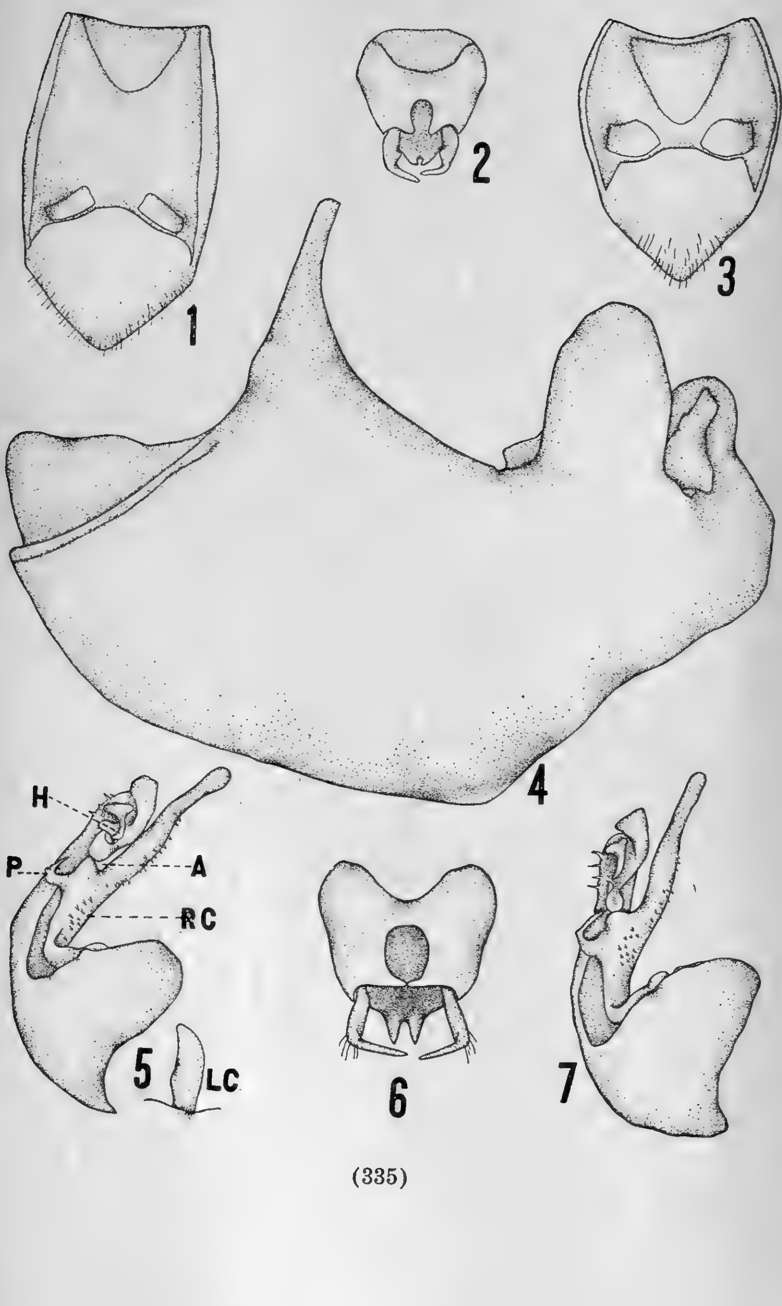
FIG. 4. *Notonecta mexicana.* The male genital capsule of this species is much larger in proportion to the size of the insect than any other member of the genus examined. It differs from the others in having the cephalic end larger than the caudal end and in having a greatly developed lobe before the clasper. The drawing is to about the same scale as those on plate 1, and the insect about the size of *N. insulata* and *N. irrorata,* the genitalia of which are shown on figures 9 and 7 of plate XXXI.

Fig. 5. *Gelastocoris variegatus* (Guer.). The specimen from which this drawing was made bears Uhler's determination and was loaned for study by Mr. E. H. Gibson, custodian of the Hemiptera in the National Museum at Washington. The drawing is made from a ventral view of the bulb. In this genus the genital segment is asymmetrical, the right clasper (R. C.) being much more developed than the left (L. C.) and armed with short peg-like processes. The segment has revolved a quarter turn to the right so that the tips of the claspers are directed to the right instead of dorsally. The general features of the genital armature are the same for all, but the western and eastern forms fall into two distinct groups as regards the shape of the right clasper. The right clasper (R. C., see figure) is produced on its caudal margin into a flat plate which bears a curved more or less finger-like process. The distal angle (*a*) which this plate forms with the shaft of the clasper is acute in all the western material and obtuse and sloping in all the eastern material examined. In Kansas we have both forms. A series from western Kansas (Pawnee county) compare closely with this Uhler specimen. As a whole, they are pebbled and colored like the sand of the river flats upon which they live. A few specimens are more obscurely marked. There is no perceptible difference in the male genitalia of the whole series, however. In the Snow collections under *G. oculatus* there are specimens from Bill Wins Ford, Arizona, taken by Doctor Snow. Some are distinctly mottled and others more obscurely marked. The crenations and angles of pronotal margins are as in the *G. variegatus* (Guer.), determined by Uhler. The right clasper is acute angled, also. They are certainly the same as Uhler's *G. variegatus* (Guer.).

FIG. 6. *Pentacora signoreti.* The genital segment of a species common in the western portion of Kansas. Determined material by Van Duzee. The two species are here shown to suggest that a study of these parts should be made in making a study of the family. They may have some taxonomic value.

FIG. 7. *Gelastocoris oculatus* (Fabr.). The specimens of the material from eastern Kansas, Tennessee, etc., as a whole, are less variegated in color pattern and from Mr. J. R. de la Torre Bueno's notes (in litt.) are probably *G. oculatus* (Fabr.). These all agree in having the obtuse and sloping angled right clasper. Kansas is splendidly situated for a study of geographical convergence. Western forms and eastern forms meet and Upper Austral and Lower Austral life zones are present. Dr. C. H. Kennedy's study of the dragon flies has directed attention to this interesting feature. One of our graduate students is now engaged in working over the distribution of the toad bugs with this point in mind. A study of a wide range of material of each form will always be essential to the establishment of the range of variation in the species, and any character which is specifically discontinuous and unique to a species is always a welcome discovery.

PLATE XXXII.



INDEX.

22—Sci. Bul.—1669

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